# SILICON CHIP

NOVEMBER 2015
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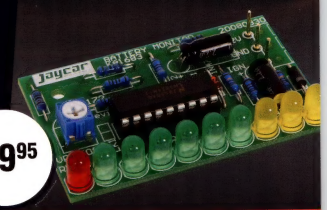

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*Kit includes PCB and all electronic components.*

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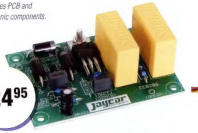

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Many modern motor bikes use a Capacitor Discharge Ignition (CDI) to improve performance and enhance reliability. However, if the CDI ignition module fails, a replacement can be very expensive. This kit will replace many failed factory units and is suitable for engines that provide a positive capacitor voltage and have a separate trigger coil.

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- Records point-of-interest at the touch of a button
- 12VDC powered

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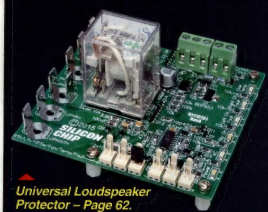

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## Hand Lever Shears

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# Publisher's Letter

## How my GPS SatNav suddenly flew out the car window

I have been using GPS SatNav units for quite a few years now and I must say I have had a love/hate relationship with them. On the one hand I continually marvel at how the signals from the constellation of GPS satellites are all brought together in a typical Sat/Nav unit to bring you maps and directions to go to virtually anywhere on the planet.

On the other hand, I have found all Sat/Nav units to be extremely frustrating at times, as most people do, particularly when you are relying on them the most, when travelling to an unfamiliar destination, when time is pressing and most of all, when you are tired. I wrote on this topic in my Publisher's Letter in the October 2014 issue and this year I thought that the latest unit I have been using, which also incorporated a dash camera, had fixed some of the problems. Well that was wrong and it had new problems of its own.

For example, occasionally on a hot day the display would simply lock up but it would continue giving spoken instructions and would even refuse to turn off. This had happened a few times but it was not until a trip from Sydney to Melbourne that it did it again. Fortunately, I had a phone with GPS and we programmed the destination in and continued on our way. Then for most of our Melbourne stay it performed without mishap until a particularly hot day when it again locked up. The remedy was the same – use a phone with in-built GPS.

Next day, on a cool morning we departed for Sydney and got onto Hoddle Street, heading North. The GPS then instructed us to veer left, which I was expecting and we entered the M3 expressway. Shortly after, it took us off the expressway and in a large circuit, back onto the now very choked expressway, in the opposite direction, going towards Hoddle Street! You can imagine the sheer frustration and the flow of expletives – there was nothing I could do about it. Eventually we got back onto Hoddle Street and with the aid of the trusty map book, navigated our way out of that mess and on to the Hume Freeway, having lost about three quarters of an hour.

As we approached the Freeway, the Sat/Nav started to make sense but I was still steaming. Then as we barrelled north on the Freeway, it again started to give stupid instructions, such as turning left when that wasn't possible. I tried turning it off and I even disconnected its USB cable – it still kept blathering on. So that was how it suddenly came to fly out of the window, at 110km/h!

Mind you, I did not have the satisfaction of actually seeing it smash into smithereens. I also realised a little later that it had a perfectly good 16GB SD card which I could have retrieved before it departed the vehicle. But enough was enough. There was no remorse.

As we drove North (in stony silence), I thought about its other annoyances, such as warnings about "combined safety cameras" in Sydney's Eastern Distributor tunnel – where there are no traffic lights. Or the stupid instructions to turn left or right after the "Caltex petal station". Or how about "turn into Merri La"? La! Obviously some map has the abbreviation La for Lane and so that is what the narration says. Or what about taking the "such and such mwy"? That one had me really tricked until I realise that "Mwy" is the abbreviation for Motorway. (It really did pronounce "mwy" phonetically!) How idiotic! And I lost count of the tortured pronunciations of quite normal street names.

Clearly, people who market these GPS units don't realise just how ridiculous these instructions can be and that their products leave a lot to be desired. Companies selling GPS Sat/Nav units should realise that they have a very powerful competitor who, by and large, does a much better job of navigation. That company is Google and while you do need to have internet/data available on your phone, you don't have to do, or pay, for any map updates. Besides, mobile phone data is getting cheaper all the time.

**Leo Simpson**

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## Thanks for FM antenna project

I'd like to thank Leo Simpson for the great article in the October 2015 edition on constructing an antenna for FM radio reception. This is a project that doesn't involve trying to solder tiny surface mount components, doesn't need programming and the fault finding is pretty elementary.

Also, not to forget, it improves one's choice of listening options on the FM band.

May I ask if you could consider an article on construction of a TV frequency antenna in a future edition. I know they are easily bought but in my area they have a limited life-span due to the local ibises sitting on the elements and destroying them due to the bird's weight being too much for the light aluminium tubing. A heavy-duty home-made antenna might be the answer.

**Cliff King,**
**Oxley, NSW.**

## DAB+ data rates are inadequate

Question: are we being conned into believing that digital radio is the best thing since Marconi did his "thing" way back when? A quick scan across the DAB+ band is enough to make you ask this question.

The bit rate for a lot of the services is so low that their FM equivalent has superior audio, which does not go well for selling this new whiz-bang technology to the informed consumer. Even a basic stereo image is missing from some of these services. Yes it's better than AM but so to is FM over AM.

Why is the sound quality not that great? Could it be a lack of bandwidth? Too many services on a frequency allocation? Does ACMA charge higher fees for a better-quality service?

It's similar to digital TV; there are so many services multiplexed on a frequency allocation we can only have one lousy HD channel per network. What a crock that is!

I believe the powers-that-be are milking this cow for all it's worth at the expense of a better product.

**Denis McCheane,**
**Allawah, NSW.**

## Working with SMDs can be rewarding

The Publisher's Letter, "SMDs Present Challenges and Opportunities", in the September 2015 issue was great. In previous issues and again in the October issue, readers find the challenges involved in using SMDs daunting. Suffering from the same worries for quite some years, I finally forced myself to replace a few SMD components to repair some circuit boards.

With a little practice, it turned out not to be so frightening after all. Get a few SMD tools together and some dead boards and give it a go. You cannot do any damage and learning by doing really is very rewarding. There have been a number of articles on removing and fitting SMDs in the magazine and I have found them to be most helpful.

For the last three decades, my development and manufacturing has been done using through-hole components. I had shied away from SMDs for many of the same reasons that have been raised by readers but last year I "bit the bullet" and have gone over to all SMD designs and have also been making my own SMD prototypes.

Breadboarding was developed well over a century ago, before printed cir-

## EMI is becoming all-pervasive

Since retiring at the end of 2012 I have reconnected with my interest in old (and new) radios and the like. However, there seems to now be more interference in the radio services spectrum then ever before. I am lucky in that I live on a small property with no near neighbours and no power lines, so the noises generated are mainly from within.

Culprit 1: the solar power inverter. My workbench is in a shed with panels on the roof and the inverter is inside the shed. This causes substantial noise in AM valve radios on the broadcast band, which can be reduced by an outside antenna.

Culprit 2: compact fluorescent lamps. Some of these are amazingly noisy, to the point of being unable to listen to the AM broadcast band at all.

Culprit 3: LED halogen downlight replacements. Here we ramp up the technology. DAB+ radio works really well despite my location but turning on downlights fitted with LED globes brings instant silence. I think I have invented remote muting for my stereo system: lights on = radio off; lights off = radio on.

Culprit 4: the NBN fixed wireless system. I love the speed, VoIP and all the other stuff I can now use but the noise is incredible. I cannot have my 1960s Kriesler (11-81A) on in the same room where the NBN modem is located. No matter which way I face the set, there is the same amount of noise. It is not in the mains; if I drive the car under the carport, radio reception is replaced by noise. Prior to the NBN, there was no problem.

If I walk around the outside of the house with a modern portable receiver (Tecsun PL880), there is plenty of noise on the medium-wave band. Compared to the above four culprits, my many computer devices from iPhones to an Intel Xeon server are unobtrusive little beasts. Does anyone else have these issues, or am I the last person to listen to MW radio?

**Jo Scheiffers,**
**Belvedere, SA.**

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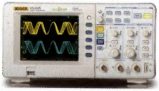

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## Mailbag: continued

### SMDs make electronic products more robust

Your September Publisher's Letter is bound to be a good conversation starter. Over 50-ish years of electronics enthusiasm, I have built a number of kits – mostly EA/SC kits – but I must admit I have yet to take on a kit with more than just a couple of SMDs, even though I have most of the assistive bits that you mentioned. A big "plus" for SMD that you didn't mention is robustness.

When I saw SILICON CHIP's review of the AirWheel in the February 2015 issue, it was love at first sight. I bought an AirWheel X8. After about 12 hours of training, I had reached passable competence and now I get looks ranging from disbelief through curiosity to wild appreciation. Back to SMDs and robustness: My AirWheel took quite a bit of punishment as I was learning, and I occasionally still have the odd minor mishap. The gadget hasn't missed a beat. Although I haven't "lifted the bonnet", it's a fair bet that the electronics, all the way from the gyro and through the controller to the motor drive, are all SMD. I can't imagine the product being as robust otherwise.

Likewise, more common forms of consumer electronics, phones, music players and the like will take a real hammering these days, compared with the old days when dropping something like that was close to a death sentence. More power to SMDs, I say. Mates tell me they're not so hard to work with – one day I'll bite the bullet.

**Neil Higgins,**
**Grande, Qld.**

cuit boards were even a flicker of light at the end of the tunnel. With the current methods of making DIY circuit boards at home, life has become so much easier and it does not take long to make an SMD prototype (nee breadboard). There is a lot of free software to design circuit boards and once you get the gear to make your own boards, it becomes really quick and easy. Suck it up and have a go! You will be thoroughly rewarded with a good-looking, compact device instead of a rat's nest covering half your table.

As for fitting the SMDs to the boards, 0805 is as small as I want to go for prototyping (probably due to my failing eyesight), even when using a large illuminated magnifier. Use of a hand-held 10x illuminated magnifier is required to read what is on some of the chips and get their orientation correct. As for actually soldering the components, a weight with a long scribe (dentist's pick) attached will hold the component in position on the board. The component can be prodded into final position and hand-soldered. Practice makes perfect (or near enough for government work!).

If a 70-year-old can learn new tricks then you can too. Go on! Expend a bit of time and the rewards will show themselves handsomely.

**Lee Bourgeois,**
**Mittagong, NSW.**

### A hot-air rework station is a boon for SMDs

I have been working with SMDs since their inception in the late 1970s. At the time I thought why would you want to make anything so small? Little did I know what was to come! In those days we had no special tools to use, only a trusty soldering iron and experience.

Over the years, I have used and tested virtually every type of rework station available, the most unusual being an infrared unit which worked extremely well but, for some reason, it didn't "take off".

The one tool which I always prefer however is the hot-air rework station. I have just purchased a Tenma unit from Element 14 for only $206 + GST. It included five different nozzles. It's a great piece of kit that the home hobbyist could use (I am now in this category since I have now retired, but still like to "play"). You can also get these hot-air stations on eBay for as low as $60, which is really great considering the prices of some of the original stations I purchased in the past.

I would suggest to any reader to obtain some old surface mount loaded PCBs and practice on these. All you need to remove a component is some flux, either gel or liquid. Place the flux generously on the pins, turn on your hot air gun and using the right nozzle, hold it just above the component pads of the part to be removed.

It doesn't take long for the solder to melt and you can then simply move the part away from the area with tweezers or such like. Next, clean the pads gently using solder-wick to remove any remaining solder. I then use a solder paste syringe with a plastic tip. The solder paste can be a bit expensive but again, eBay has it at varying prices. Place a small line of the solder paste along the pads; don't worry about the paste going between the pads as the capillary action pulls it onto the pads when heated.

Place your new component (or the old one if you're practising) onto the pads. You don't have to worry too much about the alignment, as again, capillary action pulls it into place; near enough is close enough. Get the hot-air gun and again, holding it just above the pads, apply the heat until the solder melts. Check the pads under a magnifier to make sure there are no shorts and the component is soldered sufficiently.

It won't take long to get the hang of using these tools and you will find that it will make using SMDs a much simpler task. Hope this helps.

**Mike Flor,**
**Wyongah, NSW.**

### Fine solder must be used with SMDs

The Publisher's Letter of September 2015 discussed the use of SMDs and their challenges and I must agree that they are not as hard to use as it would seem. It simply depends on how they are used. Most people would follow the conventional method and try to use solder paste etc. However, they can be soldered in the same manner as through-hole components with relative ease. Just use the appropriate tools.

I was very fortunate some years ago to retrieve a reel of


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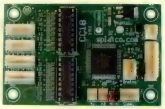

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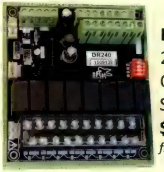

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## Mailbag: continued

### Basic unit of energy is the Joule

It was interesting that Aussie Kanck in the Mailbag pages for the September 2015 issue chided the Publisher, Leo Simpson, for referring to "power being exported back to the grid" then talks about "electrical energy (in amps) that has actually flowed into the grid". To me these are equally as bad as each other.

If you are talking about electrical energy, then amps are not much use without volts. Kilowatt-hours (kWh) are a very easy unit of energy to calculate from power and time and everyone thinks they know that you pay for "power". I wonder how many people really understand that the basic energy unit is the Joule and that a kilowatt-hour is actually 3,600,000 Joules.

**Alan Torrens,**
**Hornsby, NSW.**

*Comment: if you have a gas bill, the units are megajoules.*

0.3mm solder from a friend's electronic recycling business. By using a soldering iron with a 0.5mm conical tip, a very fine pair of tweezers, some solder wick and a jeweller's loupe, I have been able to solder discrete components in 0603 size and ICs in TQFP and TSSOP packages (0.5mm pin pitch).

I have found that it is very important to use 0.3mm solder, otherwise, it is impossible to control the amount of solder applied. I know that 0.7mm solder cannot be used and I haven't tried 0.5mm solder but I suspect that it may be acceptable.

Also, the condition of the soldering iron tip is critical. It needs to be a dry tip, ie, no free solder. Otherwise, again, it is difficult to control the amount of solder applied. Most times, the soldering is acceptable but with ICs, bridging nearly always occurs, and then the solder-wick pays for itself.

The discussion of a multi-purpose processor PCB in the September Publisher's Letter reminded me of one of the biggest faults that I see in almost all GP processor PCBs. There are insufficient ground and power connections. My first slave controller design had only one I/O connector with two 0V pins, one +5V pin and six I/O pins. With several sensors requiring only one I/O pin plus 0V and +5V, it became a pain (and costly) to make the associated wiring harnesses.

When I designed the slave controller for my current robot, I brought 12 I/O pins out as a 20-pin IDC header with four 0V and four +5V pins. Another six I/O were brought out as 3-pin KK type headers, each with 0V and +5V. As well, the configuration of the 3-pin headers is the same as that used for RC servos: pin 1 = 0V, pin 2 = +5V and pin 3 = signal. I must admit it is not perfect. The pin functions are not always where I want them but at least the wiring is so much easier.

**George Ramsay,**
**Holland Park, Qld.**


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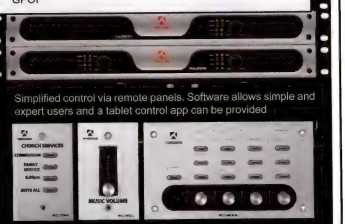

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## Mailbag: continued

### Grid supply charges will keep going up

In the Publisher's Letter in the October 2015 issue, Leo Simpson suggests that the electricity retailers "would quickly modify their tariffs and daily service charges, in order to retain as many customers as possible" to counter people going off-grid.

In Western Australia, the relevant minister is talking about how solar users are getting the use of the grid too cheaply. The government appears to be planning to raise the service charge. I don't hold out much hope that this is going to reduce the number of users going off-grid.

The argument is that the service charge does not cover the cost of the service and the usage charge includes an amount to make up the difference. This disadvantages those that cannot afford to install solar. The next few years, as batteries become cheaper, are going to be very interesting!

**Colin Carpenter,**
**Mossman Park, WA.**

### Using PA transformers in the Currawong may be a poor choice

Consider the design of a push-pull transformer for any device type of your choosing (two valves, Mosfets or bipolar transistors), any power level and any frequency range. One design parameter can be drawn from the use of the term "push-pull" and that is that it is most important that the winding for each device has exactly the same number of turns. This will ensure that even harmonics cancel for AC signals and that the total magnetic flux in the transformer due to the matched DC current of each device is zero.

If the transformer is for use with valves and "screen taps" are required, then those taps must be provided at exactly the same turn count for each half of the winding. Whether that results in 40% screen taps or 43% screen taps is less important.

Now consider the design of a 100V PA transformer. Here we need a transformer that can be connected to a 100V PA line and have various primary taps to provide different power levels to the speaker connected to the secondary. Due to the ratios of those power taps, it is quite possible that there may be sections of the primary that have the same number of turns as another part but that is purely a function of those nominal power ratios ie, the manufacturer has no interest in controlling those turns ratios at all.

After all, they've probably given a specification that the 5W tap will sup-


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ply between 4.5W and 5.5W if 10% accuracy is specified. Beyond meeting that specification, they don't care how many turns there are for each tap. If the transformers are wound by an automatic machine, every transformer may have the same number of turns in each section. If they are wound on a machine where the turn count is controlled by a human operator, the number of turns may differ from one device to the next.

So if we decide to use a PA transformer for a push-pull valve output transformer the parameter that was vitally important is not controlled at all and may even vary between transformers. Using other power taps for screen connections may compound the problem, so for example, one output valve may have a 44% tap and the other a 42% tap.

Thank you to Alex Sum (Mailbag, May 2015) for your table of calculations based on the power ratios of the Altronics PA transformers but what is really needed are some measurements regarding the actual turns ratios of the windings.

Are there any readers who have PA transformers and sufficient test equipment to replicate the set-up used for Figs.3 & 4 of the "Currawong Revisited" article from March 2015? Since being able to resolve a single turn of the primary is important, applying sufficient voltage to the 8-ohm winding to achieve 100V across the common to 15W part of the primary winding will allow the best resolution and a test frequency of more than 100Hz (from Fig.4) will be required.

There is no need to put a load on the primary as we are only interested in voltage ratios but a series "safety" resistor on the 8-ohm side may protect your source from back-EMF. Thank you also to SILICON CHIP for Figs.3 and 4. I'm sure anyone using the M1115 PA transformer as a PA transformer will find them informative. Unfortunately they are NOT being used in that same way in the Currawong so those figures are completely irrelevant in that context.

Now to Fig.7 on page 77 of the March 2015 edition. The caption for this figure is as follows "a comparison of the distortion performance of the M1115 and Hashimoto transformers at 1W without negative feedback. Surprisingly, the M1115 has much lower distortion". In my opinion, the Hashimoto transformer plot is showing the distorted drive signal being applied to the M1115 transformer to compensate for the fact that there is no centre tap on the M1115. The Hashimoto transformer is entirely blameless.

Even worse, while the Currawong is applying an asymmetric AC drive signal to the output valves to compensate for the asymmetric transformer winding, there must be a constant flux level in the M1115 transformer core due to the fact that equal DC currents in each valve will result in a net flux in the transformer because the number of turns on each side of the 5W "centre tap" are not equal.

So I encourage any readers capable of making measurements on an M1115 transformer (or any other PA type) to submit their results for publication in the "Mailbag" section. Do any of them have an equal number of turns on each side of a nominal centre tap?

**Ian May,**
**Para Hills, SA.**

### Appeal for a forward/ reverse contactor

I wonder if I might appeal to your readers for help. I am involved with a small charity organisation providing water aid relief to third world countries which involves a variety of engineering-based projects concerned with fabricating improvised drilling rigs, storage-tank rotational moulding, electric pump-controllers, etc.

I have so far been unsuccessful in

## Mailbag: continued

### DIY off-grid solar system

It's great to see so much reader interest in solar power systems! Can SILICON CHIP do an article on a home solar power system design? In particular, an off-grid system? I'm sure there are many readers who are capable and willing to go down that path.

My opinion is that grid-connect solar is a con. It's designed and promoted by the electrical supply industry, with the assistance of influenced government bodies, for the benefit of the electrical supply industry. The "benefits" they promote for the home-owner are really only clever marketing.

Think back to the smart meter installation – how much did your bills go down when they installed the smart meters and eliminated meter readers? About zero? And you even paid for the new meter!

Coal-generated power costs them 8c/kWh yet for your solar-generated power they pay only 6c/kWh (in Victoria). You (and the taxpayer) pay for the relatively large cost of small scale generation and they get the benefit of cheaper power and reduced infrastructure costs. Sure you can reduce your bill sometimes but the biggest beneficiary is the power industry. Don't forget they hit you hard with increasing daily supply charges, even when you reduce your energy use.

That's why I say if you go solar then go off-grid. Give yourself 100% of the benefit rather than some to yourself and most to the power companies.

**Robert Hatvani,**
**Noble Park North, Vic.**

tracking-down a Sprecher & Schuh forward/reverse contactor pair (on mechanical interlock baseplate), type (late-series) CA 1-14 (or even a CA 1-12), also a CS-1 control relay – all 24VAC coils which were extant ~late 1970s/early 1980s and are of a special design. Does anyone have an unwanted set in serviceable condition to donate?

Offers need not be restricted to the southern hemisphere. We also have an on-going, sporadic need for other items of surplus/salvaged industrial switchgear. Indeed, central Europe sits atop an e-waste mountain from which even a small fraction of recoverable items could be salvaged and re-purposed for humanitarian projects such as ours. Please feel free to contact me via pyralog@yahoo.co.nz

I also thought you might be interested in this suggestion for a future project. How about a film-thickness meter for those who, for instance, are into painting their own cars? Obviously, capacitance would be the prime principle to employ, the metal panel constituting one plate and then a hand-held probe and the necessary conversion circuitry to display the thickness.

**Andre Rousseau,**
**Papakura, NZ.**

### Absurd consequences of green energy

Australia and the Western world are spending vast amounts of money installing wind and solar power although these only provide power when the wind is blowing and the sun is shining. They are expensive and do not provide base load. Since their power output is constantly varying, conventional power generators in the rest of the electricity grid have to constantly vary their output to keep the grid power stable. Germany's power grid is extremely unstable due to its heavy reliance on solar and wind and it constantly has to import power from other countries. Australia does not have that luxury.

Proponents of wind and solar say that base load can be provided by battery power and hot-salt storage but there seems to be a failure to appreciate the massive amounts of energy involved, the cost of the storage and in the case of battery storage, its limited component life.

A further problem with wind power is that overall output is only 25-30% of "nameplate" capacity as most of the time the blades do not rotate. Fossil fuel is required to back-up alternative energy.

There are also some absurd consequences to "green" energy. Forests are actually getting cut down in the USA to feed wood to the Joseph C. McNeil Generating Station in Vermont. USA forests are even being cut down and shipped across the Atlantic to feed the Drax Power Station in the UK. Who would have thought the Greens would be the cause of protecting coal and destroying forests? – see http://joannenova.com.au/2015/06/what-green-vision-us-forests-burned-to-make-costly-uk-electricity-and-produce-more-co2/

In short, the world is wasting trillions of dollars on abating "global warming" when the scientific analysis is simply defective. How this came to be is beyond the scope of this letter but consider the contribution of vested interests benefiting from alternative energy and an education system where critical thinking is barely taught any more.

SILICON CHIP readers don't need to be told this but we need energy to live well. In fact, the more energy we use, the better off people are, as measured by the human development index – see www.vox.com/2015/7/13/8908397/11-charts-best-time-in-history

That is not to say we should not make any efforts to conserve energy. However, people should not have to suffer due to the high cost of green energy. There is evidence of people dying due to "energy poverty" or "fuel poverty" – see "The scandal of Britain's fuel poverty deaths" at www.theguardian.com/big-energy-debate/2014/sep/11/fuel-poverty-scandal-winter-deaths or Google "fuel poverty deaths".

In 2011, Australia's electricity consumption was about 10,700kWh per capita per year but this has sadly come down as people choose to either freeze or swelter due to the high cost of electricity. When our energy policy was decided by professional engineers and not politicians, we had access to almost limitless, inexpensive energy and the electrical grid was stable and easy to manage, as befits an advanced and energy-rich country like Australia. We now have an increasing contribution of expensive alternative energy which will work to Australia's detriment.

**Dr David Maddison,**
**Toorak, Vic.** SC

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# ORGANIC

## (and why things conduct electricity)

**Organic semiconducting materials will enable the fabrication of large, cheap printable solar panels, cheap disposable medical sensors, flexible display screens, ultra-cheap RFID tags and cheap, disposable chemical sensors.**

by Dr David Maddison

**An organic material is carbon-based** and organic semiconducting materials are usually in the form of polymers (like polyethlylene, the common packaging plastic).

Organic semiconducting materials combine some properties of traditional semiconducting materials such as silicon with properties of plastics such as low density, flexibility and the ability to produce them cheaply in large amounts.

For background on this topic it is first necessary to see why some materials are insulators, some semiconductors and some conductors.

### Why materials are conductors, insulators or semiconductors

Materials are traditionally thought of as being electrical insulators (which will not pass any significant electrical current), such as plastics like polyethylene; semiconductors (which will pass some electrical current but with some resistance), such as silicon; and conductors (which will pass electrical current with ease and with limited resistive losses), such as copper.

In electronics, materials with the properties of insulator, semiconductor and conductor are all used in nearly all devices.

Take for example a simple solid-state diode: it will have conducting metal leads, an insulating body and the active junction will be made of some combination of semiconductor materials.

### What *makes* something an insulator, semiconductor or conductor?

It comes down to the "electronic band" structure of a material. In the classical model, all matter is composed of atoms and each atom has a nucleus surrounded by electrons. The electrons have certain energies associated with them and the particular energy a certain electron has will determine which of a range of permitted energy levels or atomic orbitals in the atom it can occupy.

The Pauli exclusion principle says that no two electrons in an atom can have the same energy states and as a result of that, energy levels in atoms become occupied with electrons that all have unique energy states.

Incidentally, this exclusion principle is one of the most profound observations of nature and governs the make up of the elements and the Periodic Table.

A single atom in isolation will have a number of discrete energy levels occupied by its electrons (a bit like planets orbiting a star – see Fig.1) but when a large number of

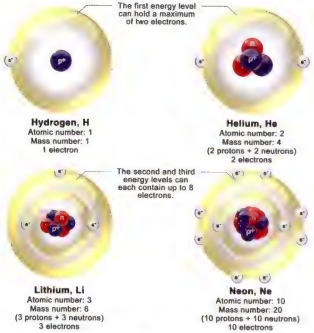



**Fig.1: this shows some energy states of an atom and how different elements have different numbers of electrons. An energy level does not have to be filled to capacity with electrons. This diagram shows the first two energy levels. The nucleus contains protons and neutrons, (ie, except for hydrogen which usually contains only one proton unless it is a heavier isotope). The nucleus in reality is about 100,000 times smaller than the atomic radius.**

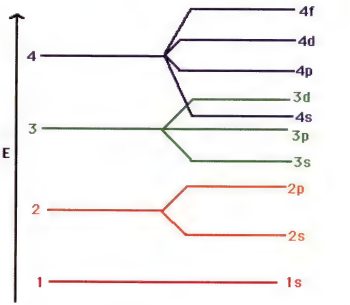



**Fig.2: there are a number of energy levels in an isolated atom. Whilst the previous diagram showed an atom with the first two levels. This shows four energy levels. In fact there are seven main energy levels. Each of the levels except the first is subdivided into a number of sub-levels, which are described with a number and letter as shown. The energy levels are filled first from the lowest to the highest.**

atoms are bought together to form a solid, these discrete energy levels merge into what are known as bands, so essentially there is a continuous range of energy levels rather than discrete levels.

This happens because all the energy levels of an atom start interacting with others, splitting into more and more levels when atoms come close together, forming so many separate levels that it is as though they were continuous bands of energy (see Fig.3).

Fig.4 (overleaf) shows the band structure in insulators, semiconductors and conductors. We can see the valence band and the conduction band, along with a "band gap".

For a material to conduct, electrons have to be available in the conduction band where they can move through the solid from atom to atom. For electrons to reach the conduction band they have to come from the valence band by crossing the band gap.

In a conductor, the valence and conduction bands overlap, so there are always electrons available to conduct electricity.

In a semiconductor there is a band gap to cross. Electrons can't easily move through the solid from atom to atom, although some will get through due to thermal excitations of the electrons.

One way to increase the small number of electrons crossing the gap is to heat the semiconductor and as the temperature increases, more and more electrons go into the conduction band so the conductivity of the semiconductor increases. Light can also excite electrons to cross the band gap.

Another way is to "dope" the semiconductor which has the effect of generating extra energy levels and reducing the size of the band gap making conduction easier. This doping is either of an "n" or "p" type, a terminology familiar to the description of a transistor as an "NPN" or "PNP", and referring to whether the charge carriers are either electrons or "holes" (absence of electrons).

In an insulator, the band gap is so large that electrons cannot cross it and move from atom to atom so very little or no conduction can occur.

## History of plastic materials

The first synthetic polymer or plastic was introduced in 1862 by Alexander Parkes, who created a mixture of cellulose nitrate and solvent which could be moulded with heat and pressure.

Following that, collodion, a cellulose solution in an alcohol-ether mixture was used by John Hyatt in 1868 to coat billiard balls. He obtained a patent in 1870, later ruled

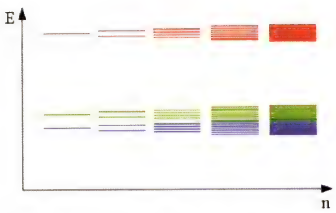



**Fig.3: discrete energy levels in a single atom on the left split into more and more levels as more atoms (n) come together, eventually forming a series of what look like continuous bands (although in reality they are a large number of separate energy levels). There may or may not be a gap between the upper and lower bands. (Image by Norbert Heinz.)**

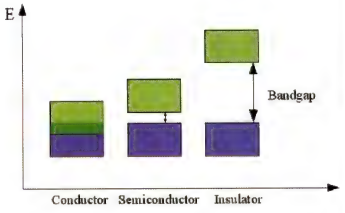



**Fig.4: valence band shown in blue and conduction band show in green for different materials. (Image by Norbert Heinz.)**

invalid, for a horn-like material of cellulose nitrate and camphor which came to be known as celluloid.

The next important polymer materials, introduced around 1897, were casein plastics, made from milk protein and formaldehyde.

This was followed by phenol-formaldehyde resins in 1899, which were originally used to replace Ebonite in electrical insulation. The phenol-formaldehyde reaction system was extensively studied and by 1907 the reaction could be well-controlled to give products with the desired products. These phenolic resins became commercially successful and are still in use today.

After the success of the phenolics came the use of urea and thiourea as a substitute for phenol. This products could be moulded in light colours, not just black as with phenolics.

Some of these polymers are still in use today.

The period 1930-1940 was when most of today's important commodity plastics were developed commercially, including polyvinyl chloride (PVC), polyethylene, polysty-

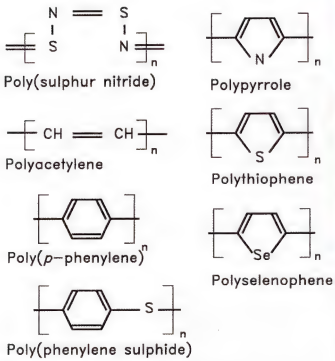



**Fig.5: a range of conducting polymers showing their molecular structures. Note their pattern of alternating single and double bonds (by author).**

**The author in his "white coat and safety glasses" days about to measure the temperature dependence of electrical conductivity in a polypyrrole sample (actual specimen not visible). A "four probe" method is used to measure conductivity to eliminate the effects of contact resistance. One vessel (left) contains liquid nitrogen and the other is an ice/water reference junction for the thermocouple. If the log of the conductivity of a specimen is plotted against temperature to the power of minus one quarter, that is evidence that electron conduction in the material occurs due to the hopping process as mentioned in the text (more specifically known as Mott Variable Range Hopping).**

rene and poly-(methyl methacrylate) (PMMA - commonly known as Perspex). Research was extensively accelerated during World War II.

## History of organic conductors

All of the plastics mentioned above are insulators, although in some applications some could be rendered slightly conductive by the addition of conducting powders or fibres such as carbon or metal.

Organic conductors or semiconductors conduct electricity without the addition of a conducting medium. These conductors may be in the form of non-polymeric compounds or in the form of polymers.

The first known electrically-conducting organic compound was made in 1862. The substance, later identified as the polymer polyaniline, was not put to use, probably because there were no identifiable uses at the time.

Just as polyethylene is the archetypal non-conducting polymer with its simple structure, polyacetylene is the archetypal conducting polymer (see Fig.5). It was first discovered in 1958 but it was not until 1971 that a laboratory mistake led to a silvery, highly-conducting form being discovered.

Then in 1977 it was discovered that the conductivity of this material could be greatly varied (by orders of magnitude) by varying the amount of iodine doping. That work led to the Nobel Prize in Chemistry for 2000.

Polyacetylene was seen as an organic equivalent to traditional semiconductors such as silicon, which could also have their conductivity greatly varied by doping. The ability to vary or engineer electronic properties marked the beginning of the field of what is now known as organic electronics.

Another early conducting polymer was polypyrrole. It was known to be able to conduct electricity since this property was discovered by an Australian group in 1963 when it was synthesised by a chemical method (see **www.drproctor.com/os/weisspaper.pdf**). It did not become widely studied until 1979, when it was synthesised by an electrochemical process, which made it simple to fabricate in film form and in reasonable quantities.

In the most basic form of the electrochemical synthesis process you have two inert electrodes, an anode and cathode, a power supply and a vessel containing the chemical reactants.

With the appropriate reactants, a polymer like polypyrrole will grow on the anode and is then peeled off.

Incidentally, organic semiconductors are not unknown in nature. Carotene, a form of which gives carrots their orange colour, is also used in the photosynthesis process is an organic semiconductor. There are also substances in the retina which are organic semiconductors.

Fig.5 also shows another related polymer, polythiophene. This will be discussed later.

## Electrical conductivity in organic semiconductors

The diagram of the molecular structures of various conducting polymers shows that they all have a system of alternating double and single bonds, which allows electrons to easily move up and down the polymer chains.

This allows conduction of electricity in one dimension, when the material is appropriately doped. If the material is crystalline, a band structure will be formed as described above.

Many organic conductors are not as crystalline as metals or semiconductors like silicon and can display significant irregularity or disorder in their structures. In these types of materials there are not extended bands but a series of localised states which electrons "hop" between in order to conduct electricity.

As can be imagined, when electrons have to "hop" from one place to the next instead of moving in a continuous band of energy, they are impeded and so efforts are directed to making more crystalline forms of these materials or otherwise minimising the energy barriers encountered by electrons.

Poly(3-hexylthiophene) (a variant of polythiophene), is of particular interest in organic electronics because of high electron mobility (the ability of an electron to move within a structure) due a more ordered crystalline structure. Another organic molecule of interest for organic electronics is pentacene which has an extended long chain structure of alternating single and double bonds similar to but not a polymer.

## Organic electronic devices

The development of organic electronic devices is proceeding quite rapidly and devices such as OLED (organic light emitting diode) displays, which were the first to be developed, have been widely commercialised.

Because of the inherent flexibility of organic chemistry, it is possible to customise chemical groups attached to a poly-

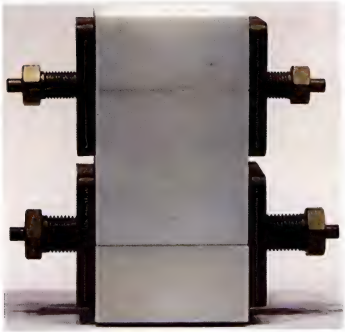
## Organic electronic research in Australia

Organic electronics is a diverse discipline requiring the input of chemists, physicists, materials scientists, engineers and many other specialists.

In Australia there are over 100 researchers working in six universities and the CSIRO. There is no formal overriding organisational structure but there are high levels of informal cooperation.

The main Australian research organisations are as follows:

- **Priority Research Centre for Organic Electronics (COE)** at the University of Newcastle. **www.newcastle.edu.au/research-and-innovation/centre/coe/about-us**
  See video "Centre for Organic Electronics - University of Newcastle, Australia" **https://youtu.be/kXQKz7YwvyM**
- **The Intelligent Polymer Research Institute** at the University of Wollongong **http://iprl.uow.edu.au/index.html**
- **Centre for Organic Photonics & Electronics** at the University of Queensland **www.physics.uq.edu.au/cope/**
- **The McNeill Research Group** at Monash University **http://users.monash.edu.au/~cmcneill/wordpress/**
- **The Ian Wark Institute** at the University of South Australia **www.unisa.edu.au/Research/Ian-Wark-Research-Institute/**
- **The Victorian Organic Solar Cell Consortium (VICOSC)** **www.energy.unimelb.edu.au/victorian-organic-solar-cell-consortium-vicosc** of which The University of Melbourne is the lead partner.



**An early, largely unrecognised organic electronic device from 1973. A bistable switch based on the skin pigment melanin.**

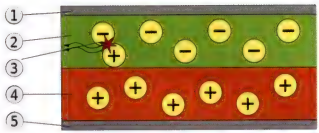



**Fig.6: structure of a typical bi-layer OLED. 1) Cathode 2) Emissive layer 3) Emission of radiation 4) Conductive layer 5) Anode. Attribution: "OLED schematic" by Rafał Konieczny**

mer chain and these groups might be designed to interact with certain molecules in the environment, if one was to engineer a device that was a chemical sensor, for example.

Many organic electronic devices are amenable to being printed and can be produced in large sizes.

## The "Printegrated Circuit"

Some readers may recall the "Printegrated Circuit", an April Fool's Day stunt in the April 1974 edition of " Electronics Australia" by who else but Dick Smith.

It was supposedly a printed electronic circuit which to be rendered functional merely had to be held up to the light to check it, then dipped in salt water.

(Unfortunately, the gag fell a bit flat because the Printegrated Circuit was printed too dark, masking the words "April Fool" printed on the following page)!

Who would have thought that around 40 years later we really would have working printable electronics?

## The first organic electronic device?

While not widely acknowledged as such, possibly the first organic electronic device was made in 1973 in the form of a bistable switch was made using the natural skin pigment melanin which has a backbone in its structure like the conducting polymer polyacetylene. A bistable switch is a fundamental element of computers.

The device is now held in "The Chip Collection" at the Smithsonian Institution (**http://smithsonianchips.si.edu** ).

## Organic Light-Emitting Diodes (OLEDs)

OLEDS are a form of light emitting diode which are based on organic materials instead of traditional semiconductors.

The organic semiconductors they use are either based on small organic molecules or alternatively, polymers.

**Left: a commercially available 128x64 resolution blue monochrome display OLED with active display area of around 22mm x 11mm. Such a module can be bought online for around $8 – including delivery to Australia.**

**Above: wearable flexible fully organic OLED display prototype by UK company Plastic Logic www.plasticlogic.com. This device contains organic transistors and can display 256 grey levels at 30fps.**

As most readers would be aware, the main application of OLEDs is in displays, as in cameras and smart phones. As they generate their own light and therefore do not require a back-light they are capable of displaying very deep black levels. They can also achieve higher contrast ratios than liquid crystal displays (LCDs) and are much thinner because they have fewer layers.

Other advantages of OLEDs include lower cost than other display technologies because they can be printed by inkjet processes or roll-to-roll; are flexible and lightweight; wide viewing angles are possible; good power efficiency (no backlight) and a fast response time, much faster than LCDs. But a disadvantage of OLEDs is a relatively short life compared to other display types.

Experiments with generating light using organic materials started in the 1950s but the first OLED based on small organic molecules was developed at Eastman Kodak in 1987, while the first device to use conducting polymers was developed at Cambridge University in 1990.

The first commercial OLED product was in 1997 when Pioneer released a passive matrix display device for car audio systems. Then in 2007 Samsung released the first active matrix display device. In 2010 OSRAM released a lighting panel based on OLED technology.

## Organic Field-Effect Transistors (OFETs)

Organic Field-Effect Transistors (OFETs) are Field Effect Transistors in which the channel is made from an organic semiconductor.

The first OFET was fabricated in 1987, based on a thiophene polymer. These devices are intended for large area, low cost and possibly disposable applications, such as biological and chemical sensors. In 2007, Sony fabricated a video display in which both the transistors and the light-emitters were all organic.

## Organic Solar Panels

Solar panels are an attractive option to be produced with organic electronic materials because of the ability to print them cheaply by high speed processes on thin supporting substrates. This would reduce the cost and weight compared to traditional solar panels which are heavy, inflexible and still rather expensive because of their extensive glass area and aluminium structures (and the inability to print them).

## Build your own Organic Light Emitting Diode (OLED)

While this has not been tested by SILICON CHIP, there are instructions available online to make your own OLED (that really works!).

See website at http://education.mrsec.wisc.edu/nanolab/oLED/index.html and http://education.mrsec.wisc.edu/299.htm

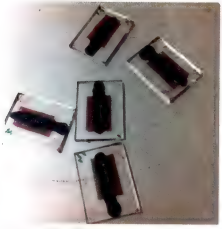
Also see the associated video "Preparation Of An Organic Light Emitting Diode" https://youtu.be/9HIrapHr8C8

While sources for the component parts and chemicals are listed, we suggest you ensure that overseas suppliers will send them to Australia and check the cost to get them here!

The University of Newcastle's (Australia) Priority Research Centre for Organic Electronics (COE), led by Prof. Paul Dastoor, is working to produce such printed solar panels using high speed printing processes, similar to the process to print newspapers and magazines and with similar equipment. The cells printed in this way have a substrate layer to act as a support structure, a conducting electrode printed onto the substrate, an active layer a few tens of nanometres thick and then another electrode.

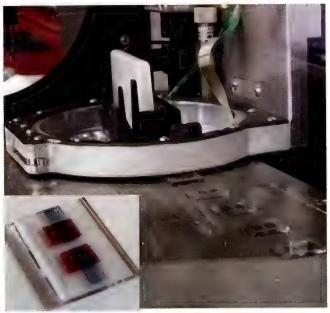
Such cells currently have a 2% efficiency; much lower than silicon solar cells but research is under way to improve this. Low efficiency might still be acceptable if they can be made extremely cheap, as the cost to generate a certain amount of power would still be less; albeit more panel area would be required than conventional solar panels.

The COE has done extensive cost modelling of these printed photovoltaics to determine the economics of



**Printed thin-film transistors for sensor applications from the Centre for Organic Electronics.**

**Representation of a commercially available OLED TV showing the fewer number of layers in the display compared to an LCD which enables it to be much thinner. In addition, the flexible nature of OLEDs makes it easier to fabricate a curved display which gives a sense of viewer immersion in the scene. (From Samsung.)**



**Fuji printer at Centre for Organic Electronics with multiple copies of printed organic transistors with close-up of printed transistor shown in inset.**

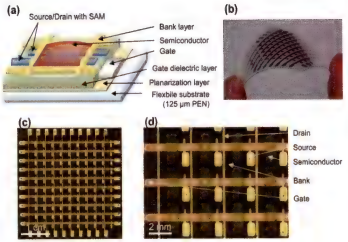



**Fig.7: printed organic thin-film transistors on flexible substrates by a Japanese group. SAM stands for self-assembled monolayer and PEN is polyethylene naphthalate. Note the relatively large size of the devices. (www.nature.com/articles/srep03947/figures/1)**

large scale production of these cells. A cost figure of $8 per square meter has been suggested for these panels, so at that low cost they could be used anywhere, even in non-optimal locations. These panels can produce power at lower light levels than silicon panels, thus generating power for longer periods.

An area of concern with organic solar panels and organic electronics in general is their long-term stability. While this problem needs to be overcome, traditional silicon solar cells outside of their hermetic packaging are not particularly stable either.

The problems related to that would be familiar to anyone who has tried to make their own solar panels from the cheap silicon solar cell wafers available on ebay.

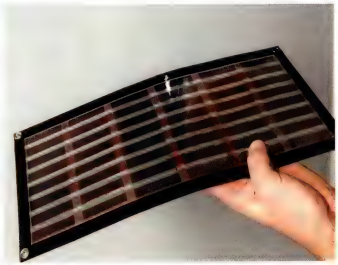
Effective encapsulation to exclude moisture and air is the most difficult part and it is vital to get it right. The economic model that Prof. Dastoor's group has developed is based upon a panel with a 2% efficiency and a service life of two years; figures optimised to give the lowest possible cost.

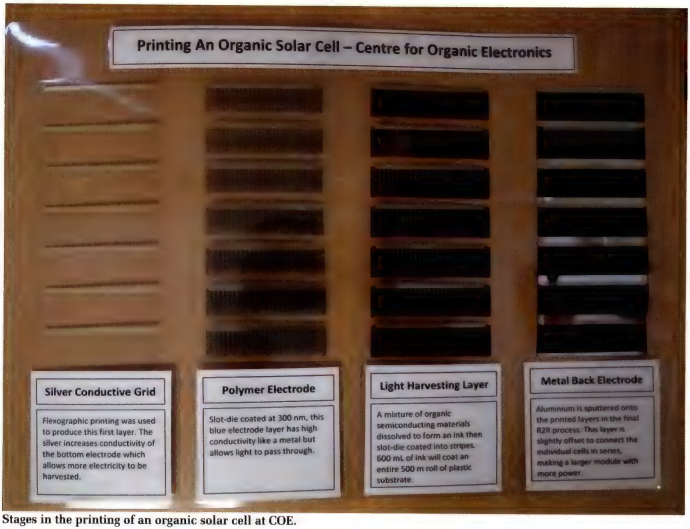
Contractors would replace the panels at regular intervals just as some commercial organisations pay specialised contractors to regularly replace their light globes. In fact, these low cost solar cells should be considered to be a similar paradigm to light globes which people already accept as having to be replaced from time to time.

While longer service life might be desirable, it turns out that the extra cost of encapsulation to do that reduces efficiency and increases material costs. Since these panels

**Left: a printed, flexible organic solar panel at COE in operation.**

**Below: a printed organic solar panel from COE in mounting frame, suitable for attachment to a building.**






**Stages in the printing of an organic solar cell at COE.**

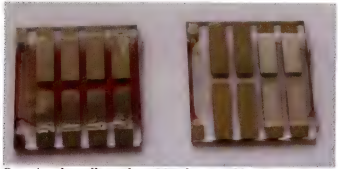
are thin and flexible, replacement might even be as simple as disconnecting an old panel and adhering a new panel right on top of it.

## Inverted device structure organic solar cells

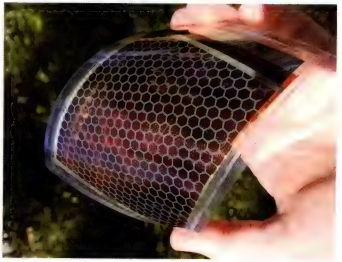
One approach to extending the service life of organic solar cells being researched at COE is to invert the structure of the solar cell so that those layers most resistant to degradation are those that are exposed to the environment and the more sensitive layers are deep within the structure (shades of the human eye?) – see Fig.8.

## Paint-on solar cells

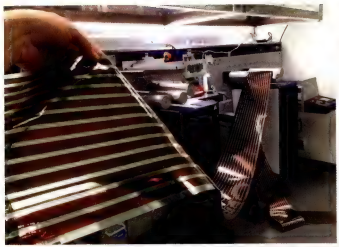
In other work from the Centre for Organic Electronics, "paint-on" solar cells are under development. These would be made from three layers: an electrode layer, an active layer



**Organic solar cell panels at COE showing "bleaching" of active cell material due to degradation (light coloured strip areas on right side of right panel) compared to other protected areas of the panel. Research is under way to find suitable methods of preventing degradation of these cells. Work has been able to increase the half life of cells from a few hours to 14 days with a hope of increasing cell stability to 2-3 years which economic modelling shows to be a cost-effective life span.**



**Another type of printed flexible solar cell fabricated at COE.**



**Continuous production of rolls of printed flexible solar cells film at COE. Note the many metres of material coming out of the roll to roll printing machine.**

**Bottle of "solar paint", precursor chemicals and continuous rolls of printed solar panels at COE in the background.**

and another electrode layer. These could be sprayed onto a building surface as a conformal coating using traditional spray painting equipment.

See videos: "Prof. Paul Dastoor's Solar Paint Technology – ABC New Inventors – Whole Part" **https://youtu.be/-O39o_ERtbg** and "Solar Power Generated with Paint" **http://on.aol.com/video/solar-power-generated-with-paint-517483009**

## Pain-free testing for diabetics using bio-sensors

Every diabetic will tell you the procedure they hate the most (even more than insulin injections) is the regular, painful "finger prick" to obtain a tiny blood sample to check their blood glucose levels.

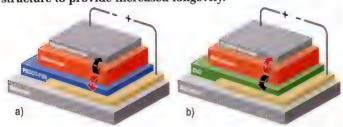
Even though glucose is also present in saliva, the concentration is about 100 times less than the blood and current equipment cannot easily measure that.

At the COE a sensitive glucose sensor has been fabricated in the form of an organic thin film transistor (OTFT).

## Electronic skins

An "electronic skin" or e-skin is under development by Japanese researchers, for medical monitoring or alternatively, as a sensor skin for artificial limbs to monitor pressure etc. The electronics within this skin are flexible and stretchable and it contains printed thin film organic transistors. For video see "Electronic Skin" **https://youtu.be/4oqf--GMNrA**

**(Fig.8, below): organic solar cell at COE with inverted structure to provide increased longevity.**




**(Right): freshly printed glucose sensor for use by diabetics. In an actual device the support film would be cut away as the device is much smaller than the support sheet. The beauty of this device is that it is sensitive to glucose in the saliva which is at a concentration of about 100 times less than in the blood.**

## Fabrication methods for organic electronic materials

Organic electronic devices can be synthesised and fabricated by a variety of methods such as traditional chemical reaction, electrochemical polymerisation, chemical vapour deposition, printing with ink jet technology or printing by a roll-to-roll process.

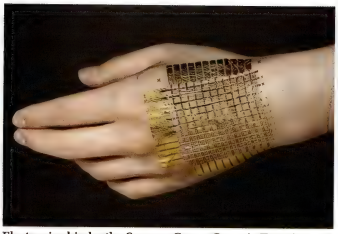
Another consideration with fabricating organic electronics is the electrode material. Some organic electronic devices require transparent conducting electrodes. In traditional devices, indium tin oxide (ITO) is used however the price of ITO is increasing due to high demand, so alternative transparent conducting electrodes are being sought.

Graphene is one possibility for such an electrode material (see article on graphene in SILICON CHIP, September 2013).

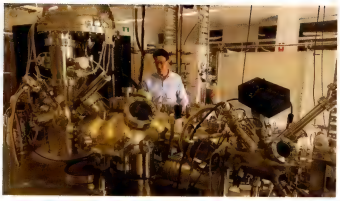
## Conclusion

Organic electronics is still in its infancy but expanding rapidly. As more and more items incorporate electronics and sensors, there will an increasing demand for flexible and low-cost devices, including devices cheap enough to be disposable.

The ability to use low-cost printing processes means



**Electronic skin by the Someya Group Organic Transistor Lab in Tokyo. Described as the world's lightest and thinnest flexible sensor system, this stick-on device is designed as a wearable health monitoring system.**

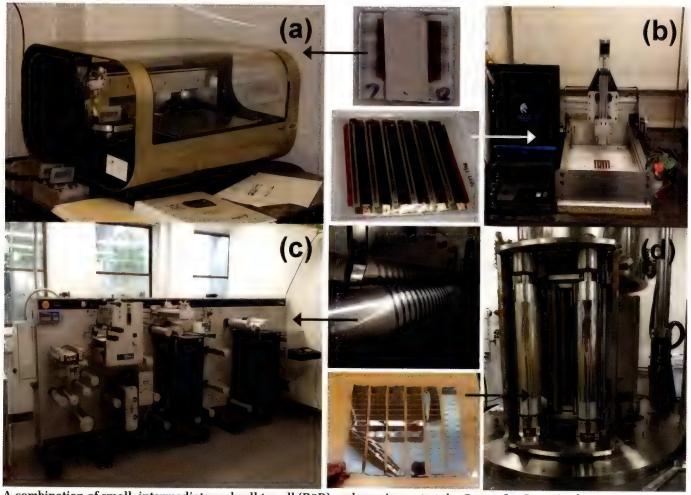


**Dr Ben Vaughan (Australian National Fabrication Facility, [ANFF]) with the surface analysis facility at the Centre for Organic Electronics, University of Newcastle.**

large numbers of devices, or large areas of devices such as solar panels, can be made cheaply.

The high levels of customisation possible in organic electronics will also enable devices to be made with very specific capabilities such as sensors to detect specific chemical or biological substances.

Traditional semiconductors like silicon and gallium arsenide will likely continue to be used for ultra-high speed devices but organics will find particular niches such as those requiring large scale, low cost, flexibility or disposability, as well as mainstream uses such as displays.




**A combination of small, intermediate and roll to roll (R2R) scale equipment at the Centre for Organic electronics. (a) Dimatix ink jet printer, (b) custom-built single head automated slot dye and blade coater, (c) R2R solar coating line from Grafisk Maskinfabrik and (d) R2R sputter coating unit from Semicore Inc. The middle images show samples fabricated with equipment (a)-(d) in order from top to bottom.**

By JOHN CLARKE

# Open doors with this Fingerprint Access Controller

## Uses a fingerprint scanner & an electric door strike

**Do you hate carrying keys? So do we! Would you like to open your front door, security gate or your garage door with your finger? Now you can! This project comprises a fingerprint scanner (FPS), a 2-row LCD and an electric door strike, all controlled by a PIC16F88 microcontroller.**

SOME LAPTOP PCs and smartphones have a fingerprint scanner to enable to you access them and now you can build a project which works along similar lines. It can store and recognise up to 20 fingerprints and can give access to your home or workplace at any time, day or night. There's no need to fiddle around with keys – all you need is a finger!

The fingerprint scanner (FPS) we have used is the GT-511C1R, manufactured by ADH-Tech in Taiwan and available from SparkFun Electronics in the USA and Little Bird Electronics in Australia. It isn't cheap at around $56 including GST but getting copies of door keys for up to 20 people can cost a similar amount.

The GT-511C1R FPS comprises an optical sensor (specifically a CCD camera) with an opaque screen (14 x 12.5mm) which you cover with your finger, to scan it. The camera records the fingerprint image which is compared with those stored in a database. If your print is in the database, the micro will unlatch the door, via the electric door strike.

As can be imagined, there is a lot of processing required to compare one fingerprint with a database and the GT-511C1R uses an ARM Cortex-M3 32-bit processor that's specifically designed for real-time data processing; ideal for processing the 240 x 216 pixel image of a fingerprint. It breaks the photographed image down into a 504 byte template that becomes a digital representation of the fingerprint.

All the fingerprint image capture, digital template data and fingerprint identification is done within the FPS but to make it work, it must be used in conjunction with a computer or microcontroller. Connection to the FPS is made via a JST-SH 4-way wired header plug which provides the DC

## Main Features

- Identifies up to 20 separate fingerprints
- LCD module guides operation
- Drives an electric door strike (latch) to open a door
- Enrolments & deletions easily accomplished
- Errors shown on LCD
- Adjustable door strike activation period
- Adjustable scan resolution
- Additional security features

power and serial lines to carry the commands and the data.

These commands are for switching on internal LEDs for backlighting the FPS screen and for enrolling or validating a fingerprint against those stored in the database. The computer or microcontroller does not need to be high-powered; a simple 8-bit microcontroller will suffice.

The data-sheet for the FPS is available at **www.sparkfun.com/products/13007** There is an evaluation executable file that can be run on a computer using a serial port (or USB to serial converter) to connect to the FPS. The demonstration file is available at **https://cdn.sparkfun.com/datasheets/Sensors/Biometric/GT-511C1R_SDK_20140312.zip**

While the demonstration file shows what the FPS can do, it is not suitable for a practical fingerprint security access system that can release the door strike of a door lock. For that we need a more dedicated circuit and custom software.

Our system combines the GT-511CR FPS with a 2-line LCD module. This module is used when enrolling fingerprints and when selecting the various options using four pushbutton switches. These components, along with a PCB containing the PIC16F88 microcontroller, are mounted in a bulkhead case measuring 120 x 70 x 30mm. The whole works is powered using a 12V 1A DC plugpack and this provides the brief power pulses for the electric door strike as well.

## Features & operation

Normally, the FPS would be mounted on a wall-plate just outside the locked door while the control box is mounted on the other side of the door. The electric door strike is a door latch and when it is powered, the latch becomes free so that the door can be pushed open.

In normal operation, the FPS flashes its blue back-lighting LEDs once a second and each time checks whether a finger is pressed on the screen. If so, the LEDs stay lit and the fingerprint is compared with those in the database. The door-strike will then be briefly pulsed to open the door, if the fingerprint is valid.

If the fingerprint is not matched in the database or there are no current enrolments or there is a fingerprint reading error, the LEDs will flash rapidly at four times a second, for 2.5 seconds. At the same time, the error will be displayed on the LCD screen.

Other errors are related to security breaches as discussed later. These will cause the FPS blue LED back-lighting to stay off until the fault is acknowledged, using the Enter button on the control panel.

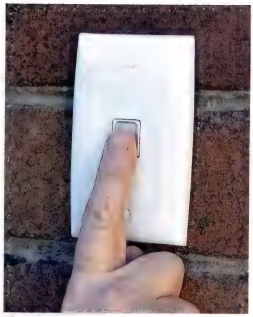
To make it work, you need to enrol one or more fingerprints so there is a database. Enrolment and other functions are done using the four pushbutton switches on the control panel. The four buttons are, from left to right: Menu, Enter, Down and Up.

Once powered up, the default home-screen on the LCD shows **Fingerprint Security Access**. Repeatedly pressing the Menu button lets you cycle through five menus, the first of which is for enrolling a new identity (ID). The ID numbers can be scrolled up or down using the buttons and only the unused ID numbers will be shown. Pressing the Enter button then starts the enrolment procedure, during which you will be instructed to place your finger on the FPS.

The next menu is for deleting an enrolled ID. Only enrolled IDs will be shown, by scrolling up or down. Pressing the Enter button deletes the selected ID.

The third Menu deletes all enrolled IDs; useful if you want to clear everything and start again. It is much faster than deleting enrolments one by one.

The fourth and fifth menus let you adjust the scan resolution and the door-strike energising period. The door-strike operating period is adjustable from 1s up to 255s. The Up and Down buttons are used to make the changes.



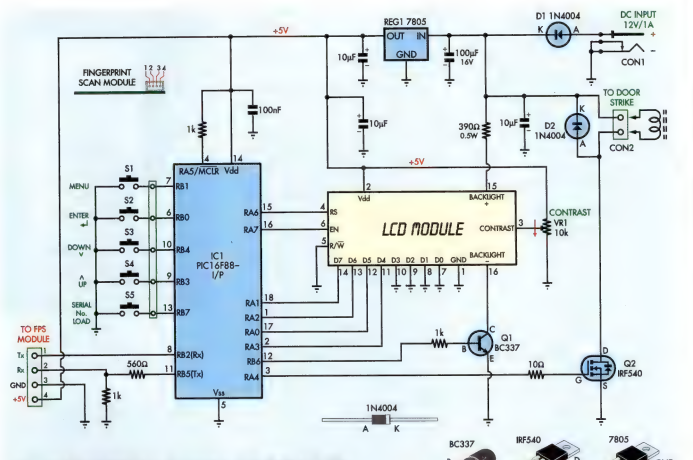
**The FPS (fingerprint scanner) can be mounted on a blank wall-plate adjacent to the locked door, while the control box is mounted inside the room.**

**Shown here slightly larger than actual size, the GT-511C1R FPS can enrol up to 20 fingerprints. The module measures just 37 x 17 x 9.5mm (L x W x D).**

The scan resolution essentially sets the resolution of the captured fingerprint during access. It does not change the enrolment resolution of the fingerprints; that's always at the highest resolution. A low resolution selection makes the database search faster compared to using the high resolution selection.

The next press of the Menu button takes the system back to the home screen. Alternatively, the system will automatically return to the home-screen after 25 seconds if a menu item is selected and no further buttons are pressed.

Note that the LCD module lights up when any switch is pressed. It also




# SC FINGERPRINT ACCESS CONTROLLER

**Fig.1: the circuit is based on a GT-511C1R FPS, PIC microcontroller IC1 and a 2-line 16-character LCD module. IC1 sends and receives data to and from the FPS module via its serial port (pins 8 & 11), monitors pushbutton switches S1-S5 and drives the LCD. It also drives Mosfet Q2 to activate the electric door strike when a valid fingerprint is scanned by the FPS. Transistor Q1 is driven by IC1's RB6 output and controls the LCD's backlight.**

lights when the LCD screen changes to indicate the type of access (whether allowed, denied or security errors). The backlight automatically turns off after 10 seconds, except for security breach errors in which case the backlight will stay on.

## Foiling security breaches

Since the FPS is likely to be located in an unsecured area, there is a risk of attempted security breaches. However, we have incorporated some features to make unauthorised tampering ineffective. First, if the FPS is swapped with another one, access will be denied because each FPS has its own unique serial number.

Second, if the original FPS is temporarily disconnected and connected to another Fingerprint Security Access controller to set up a new enrolment (eg, with the intruder's fingerprint), this too will be foiled. Access will be denied even though the correct FPS is reconnected with the matching serial number. When the FPS is reconnected and a finger is subsequently detected on the screen, the Fingerprint Access Controller will detect that the enrolments have changed. A tamper message will then be displayed on the LCD screen and all access will be denied.

Two other security measures are also incorporated to counteract any "hot wiring" exchanges of the FPS. If the FPS is disconnected and reconnected while power is applied, the Fingerprint Access Controller will immediately halt operation, preventing any access.

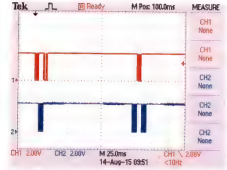
Similarly, if the FPS is quickly hot-swapped from one control unit to another using a switched lead, operation will halt. During this halt, the FPS will have its blue back-lighting off to indicate a fault. No indication will be issued on the LCD screen and the switches will not have any effect. The Fingerprint Access Controller will then need to be powered down and powered up again to restore operation.

## Circuit description

Fig.1 shows the circuit for the Fingerprint Access Controller. It comprises the fingerprint scanner (FPS), a microcontroller (IC1) and a 2-line 16-character LCD module. Each of these is complex in itself but they make the rest of the circuit quite simple.

The LCD is driven by IC1 via its four most-significant data lines (D4-D7), while lines D0-D3 are tied to ground. When driving the LCD, data is sent in two 4-bit portions to make up the full 8-bit data. Driving the display in this way saves having to dedicate an extra four connections to IC1. The EN (Enable) and RS (register select) lines are driven via IC1's RA7 and RA6 ports to control the clocking and data flow to the LCD.

The LCD module's contrast control is trimpot VR1 which is adjusted to




**Scope 1: the top trace of this scope grab shows the commands sent to the FPS during a scanning routine. First, the FPS backlight is switched on, then a check is made to detect if a finger is placed on the FPS screen. In this case, there is no finger present and so the backlighting is switched off. The lower trace shows the acknowledgement from the FPS.**

give the best screen contrast. Transistor Q1 controls the LCD module's backlighting and its base is driven with a PWM signal from IC1's RB6 output. The backlight LEDs are supplied via a 390Ω 0.5W resistor connected to the 12V supply (following diode D1).

The FPS module is driven by IC1's serial port. As shown, IC1's receive input (Rx) at pin 8 connects to the transmit (Tx) pin of the FPS module. Similarly, IC1's transmit (Tx) pin (pin 11) connects to the receive (Rx) pin of the FPS. A resistive divider reduces the 5V transmit signal from IC1 down to a nominal 0-3.3V to make it suitable for the FPS's Rx input.

The FPS uses an 8-bit data and one stop bit format and the default baud rate is 9600 baud. However, faster rates such as 19,200, 38,400, 57,600 and 115,200 baud can be selected by sending a command and baud rate parameter and IC1 actually does this, depending on its mode. Data sent to the FPS begins with four header bytes (55, AA, 01, 00) for the start bits and device ID, then a 4-byte parameter value followed by a 2-byte command value and 2-byte checksum. Acknowledgement from the FPS follows a similar format.

When reading the serial number, an extra 30 bytes of data is sent. This incorporates the 16-byte serial number, with the remainder being start bytes (this time it's 5A and A5), device ID, firmware version, size of captured image, serial number and a 2-byte checksum at the end. All data is sent and received with the least significant bytes first ("Little Endian", as the data sheet describes it).

## Specifications

### Finger Print Scanner (FPS)

**CPU:** ARM Cortex-M3 core (32-bit)
**Sensor area:** 14 x 12.5mm
**Image size:** 240 x 216 pixels
**Resolution:** 420dpi
**Maximum number of fingerprints stored:** 20
**Template size:** 504 bytes
**Communication:** 9600 baud (default) to 115,200 baud, (eg, 19,200, 38,400, 57,600)
**False acceptance rate:** <0.001%
**False rejection rate:** < 0.1%
**Identification time:** minimum of 1.5s but usually longer depending on number of fingerprints stored
**Operating Voltage:** 3.3-6V
**Current:** 130mA with sensor LEDs on
**Operating temperature range:** -20°C to +60°C

### Control Unit

**Power supply:** 12V DC @ 1A
**FPS connection:** JST-SH 4-way wired header plug lead (tested up to 1.2m long)
**Current consumption:** scanning, 150mA; FPS blue LEDs on, 200mA; door-strike on 700mA
**LCD backlight:** turns on when a switch is pressed and during fingerprint detection; automatically turns off after ~25s
**Fingerprint scanning:** detect once per second with FPS LED flashing at 1Hz
**Home screen:** appears during scanning; automatically returns after 25s if no switches are pressed during this time
**Door strike activation period:** adjustable from 1-255s
**Fingerprint scan resolution:** selectable low or high
**Enrolment control:** add a new enrolment ID, delete an enrolment ID and delete all enrolments
**Additional security:** FPS unique serial number check; check for correct number of enrolments plus two more undisclosed security techniques

The accompanying scope grabs illustrate the circuit operation. Scope1 shows the normal scanning routine where the FPS backlight is switched on, then a check is made to detect if a finger is placed on the FPS screen. In this case, no finger is present and so the backlighting is switched off. The data sent to the FPS is the top trace and is shown in the above order, ie, backlight on, check for a pressed finger, then backlighting off.

The acknowledgement from the FPS is shown in the lower trace and occurs immediately after the serial data is sent for backlighting on and off, but with a delay of around 125ms for the response while the FPS checks if a finger is present. The received serial data response length is about 7.5ms long in each case.

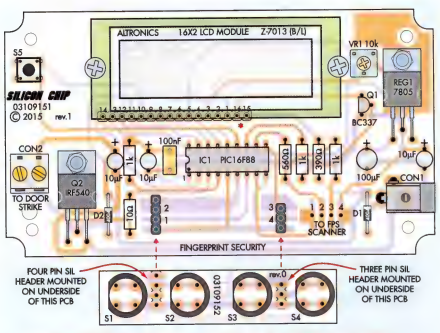
Scope2 shows the data sent to retrieve the serial number of the FPS. Note how much more data is returned, taking some 26.5ms compared to the normal response of around 7.5ms.

Scope3 shows the complete code sent to switch the FPS backlight off, expanded out to 1ms per division.

### Pushbuttons

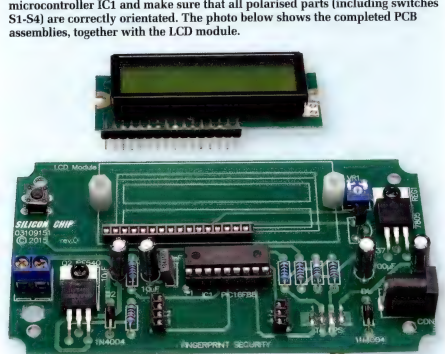
IC1 also monitors pushbutton switches S1-S5 which are connected to inputs with internal pull-ups. These hold each input high (5V) unless a switch is pressed, which pulls the respective input low (0V).

The electric door strike solenoid is driven via Mosfet Q2 and its gate is driven by IC1's RA4 output via a 10Ω resistor. One side of the door-strike is connected to 0V when the Mosfet is switched on. The other terminal of the door-strike connects to the 12V rail




*NOTE: 16-WAY SIL SOCKET ON MAIN PCB, 16-WAY SIL HEADER ON UNDERSIDE OF LCD MODULE

**Fig.2: follow this parts layout diagram to build the two PCBs. Use a socket for microcontroller IC1 and make sure that all polarised parts (including switches S1-S4) are correctly orientated. The photo below shows the completed PCB assemblies, together with the LCD module.**




via reverse polarity protection diode D1. Diode D2 quenches the back-EMF pulse produced by the door-strike solenoid when it is switched off.

## Garage door opener

The FPS does not have to be used with an electric door strike. For example, it could instead be used with a garage door opener which is triggered by shorting two contacts; shorting the contacts operates the door, either to open or close it.

In that case, the source and drain of the Mosfet need to be brought out to a 2-pin connector and then connected via a figure-8 cable to the switch contacts on the garage door opener.

Alternatively, a 12V relay could be wired to CON2 in place of the door strike to do the switching operation.

The supply for IC1, the LCD and the FPS is derived via REG1, a 5V 3-terminal regulator. A 100nF capacitor decouples the supply to IC1 close to its supply pins, while the supply for the LCD module is decoupled using a 10µF capacitor.

Power is applied from a 12V DC plugpack to REG1 via reverse polarity protection diode D1. A 100µF capacitor decouples the supply to REG1 while its output includes a 10µF supply bypass capacitor.

## Construction

All the parts for the Fingerprint Access Controller are installed on two PCBs: (1) a main board coded 03109151 (114 x 53.5mm) which accommodates most of the parts, including the LCD module; and (2) a switch board coded 03108152 (62 x 14mm) which accommodates the four push-button switches (plus two pin headers) and which plugs into the main PCB. The completed assembly is housed in a 120 x 70 x 30mm bulkhead style case with a transparent lid.

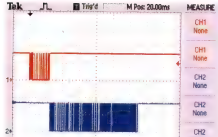
Fig.2 shows the parts layout on the two PCBs. The main board can be assembled first. Begin by fitting the resistors, taking care to install each one in its correct location. Table 1 shows the resistor colour codes but you should also use a digital multimeter to check each resistor before soldering it to the PCB.

Diodes D1 & D2 go in next (take care with their orientation), followed by an 18-pin DIL socket for IC1. The 4-way and 3-way SIL (single in-line) sockets, used to later mount the switch PCB, can then be installed.

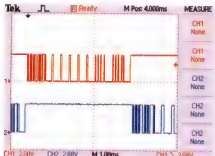
These socket strips are obtained by cutting down a DIL IC socket using a sharp knife or side-cutters. It's a good idea to smooth the cut edges with a file before installing the socket strips on the PCB. Similarly, the LCD module is mounted via a 16-pin SIL socket strip and this can also now be installed.

The capacitors are next on the list. Note that the electrolytic types must be orientated as shown.

Follow with REG1 and Mosfet Q2. These devices are mounted with their




**Scope 2: this scope grab shows the data sent to retrieve the serial number of the FPS. Note how much data is returned, taking some 26.5ms compared to the normal response of around 7.5ms.**




**Scope 3: the complete code sent to switch the FPS's back-light off is shown here, expanded out to 1ms per division.**

metal tabs flat against the PCB (ie, their leads must be bent down through 90° to pass through their respective holes). Secure each device to the PCB using an M3 x 6mm screw before soldering its leads. Don't solder the device leads first; if you do, the PCB tracks could crack as the tab screws are tightened down.

Be careful not to get Q2 & REG1 mixed up – they look much the same.

Transistor Q1 (BC337), trimpot VR1, the DC socket (CON1), the 2-way screw terminal block (CON2) and push-button switch S5 can then go in. Check that CON1 & CON2 sit flush against the PCB before soldering their terminals.

## Switch PCB

Attention can now be turned to the switch PCB. The 3-way and 4-way pin headers go in first. These are installed on the underside of the board and must be fitted with their shorter pin lengths going into the PCB holes. The header pins are then soldered on the top (switch side) of the PCB.

Once the headers are in place, the four pushbutton switches (S1-S4) can then be fitted. Install them with the flat side of each switch orientated as shown and make sure that they sit

## Parts List

1 double-sided PCB, code 03109151, 114 x 53.5mm
1 double-sided PCB, code 03109152, 62 x 14mm
1 GT-511C1R fingerprint scanner (Littlebird Electronics SF-SEN-13007)
1 JST-SH 4-way wired header plug, 200mm lead length (Littlebird Electronics PRT-10359)
1 12VDC 1A plugpack
1 bulkhead case, 120 x 70 x 30mm (Jaycar HB-6082)
1 blank wall-plate (to mount fingerprint scanner)
1 12V electric door strike (fail-secure) (Jaycar LA-5077, Altronics S 5385, S 5387A)
1 16 x 2 LCD module with back-lighting (Jaycar QP-5512, Altronics Z 7013)
4 click-action pushbutton switches, PCB-mount, white (Jaycar SP-0723, Altronics S 1099) (S1-S4)
1 SPST PCB-mount tactile switch (Jaycar SP-0600, Altronics S 1120) (S5)
1 18-pin IC socket
1 40-pin IC socket cut into 16-way, 4-way & 3-way SIL header strips
1 23-way SIL header strip cut to 16, 4 & 3-way lengths
1 PCB-mount DC socket (Jaycar PS-0520, Altronics P 0620, P0621A) (CON1)
1 2-way screw terminal block, 5.08mm pin spacing (CON2)
2 M3 x 6.3mm tapped spacers
6 M3 x 6mm screws
2 M3 nuts
4 No.4 self-tapping screws

**Semiconductors**
1 PIC16F88-I/P microcontroller programmed with 0310915A.hex (IC1)
1 7805 5V 3-terminal regulator (REG1)
2 1N4004 1A diodes (D1,D2)
1 BC337 NPN transistor (Q1)
1 IRF540 N-channel Mosfet (Q2)

**Capacitors**
1 100µF 16V PC electrolytic
3 10µF 16V PC electrolytic
1 100nF MKT polyester

**Resistors (0.25W, 1%)**
3 1kΩ
1 560Ω
1 390Ω 0.5W
1 10Ω
1 10kΩ miniature trimpot, horizontal mount (VR1) (code 103)

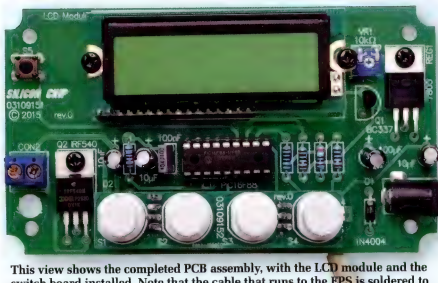
**Miscellaneous**
1 1m length of 4-way rainbow or telephone cable (length to suit installation)
1 short length of 2mm-diameter heatshrink tubing
1 length of figure-8 wire to connect door strike
1 12V bezel indicator lamp (LED or filament type) (optional to show door-strike operation)

### Where to buy a kit

A complete kit of parts for the Fingerprint Access Controller will be available from Altronics for $99.95, Cat. K 9350. This kit will include the GT-511C1R module and a punched wall plate but not the door strike.

## Table 1: Resistor Colour Codes

| ❑ | No. | Value | 4-Band Code (1%) | 5-Band Code (1%) |
|---|---|---|---|---|
| ❑ | 3 | 1kΩ | brown black red brown | brown black black brown brown |
| ❑ | 1 | 560Ω | green blue brown brown | green blue black black brown |
| ❑ | 1 | 390Ω | orange white brown brown | orange white black black brown |
| ❑ | 1 | 10Ω | brown black black brown | brown black black gold brown |




**This view shows the completed PCB assembly, with the LCD module and the switch board installed. Note that the cable that runs to the FPS is soldered to the main PCB before the switch board is fitted (see text).**

flush against the PCB before soldering their pins.

The assembled switch PCB can then be plugged into the main PCB but note that there is a right way and wrong way to install it – the 4-way pin header must be plugged into the 4-way socket, while the 3-way header goes into the 3-way socket.

## Installing the LCD

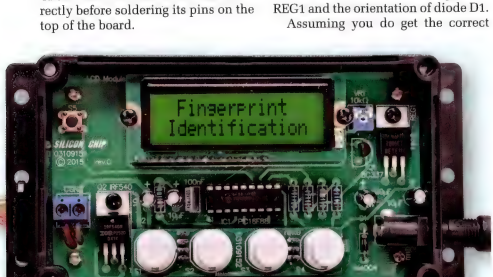
Before installing the LCD, a 16-way SIL pin header must first be fitted to its bottom edge. This is installed from the underside of the PCB with the short pin lengths going through the holes. Check that the header is seated correctly before soldering its pins on the top of the board.

Once the header is in place, cut a short strip of thick cardboard exactly 7mm wide. This cardboard strip is then used as a gauge while the header pins are trimmed using side-cutters – ie, the header pins are trimmed so that their ends are 7mm below the underside of the LCD module's PCB.

## Applying power

Before applying power for the first time, make sure that microcontroller IC1 is out of its socket and that the LCD is unplugged. Check the assembly carefully, then apply power and check that there is 5V between pins 14 & 5 of IC1's socket. If there's no reading, check REG1 and the orientation of diode D1.

Assuming you do get the correct reading, switch off and install IC1. The two M3 x 6.3mm standoff mounts for the LCD module can now be secured to the main PCB using M3 x 6mm screws. That done, plug the LCD into its header socket and secure it to the standoffs at either end using another two M3 x 6mm screws.




**The completed PCB assembly is secured inside the case using four self-tapping screws that go into integral stand-offs. The case comes with a transparent lid so there's no need to make a cut-out for the display, although it is necessary to drill holes for pushbutton switches S1-S4.**

## Preparing the case

The completed PCB assemblies can now be placed to one side while you prepare the case.

The first step is to drill a 10mm-diameter hole for the DC socket. Fig.3 shows the drilling template and this can either be copied or downloaded in PDF format from the SILICON CHIP website (**www.siliconchip.com.au**) and printed out. Use a small pilot drill to start the hole, then carefully enlarge it to size using larger drills and a tapered reamer.

Fig.4 shows the front-panel artwork (also available from our website). This can be used as a drilling template for the four front-panel switches. The holes should all be drilled and enlarged with a tapered reamer to a diameter of 10mm.

Finally, you will have to drill two holes in the base of the case – one to feed through the wiring from GT-511C1R fingerprint scanner (FPS) and another to accept the wiring that runs from the electric door-strike to CON2. Note that the wiring to CON2 is fed through the PCB via a hole immediately in front of this terminal block.

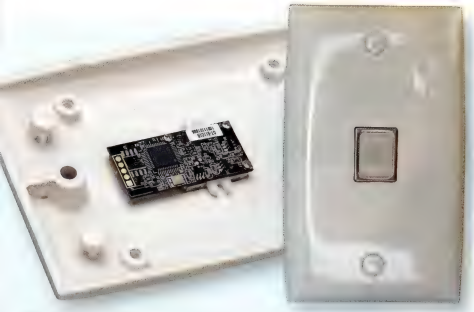
The positions of the two holes in the base are not particularly critical. The hole for the FPS wiring can be drilled so that it will be roughly in-line with the FPS pads on the PCB. The door-strike wiring hole can be positioned in-line with this first hole, so that it will sit more or less behind Q2.

Note that the wiring connector for the FPS is fitted with a JST-SH plug (see parts list). This means that the FPS wiring hole will need to be large enough for the JST-SH plug to pass through.

## Extending the leads

As supplied, the lead fitted to the JST-SH plug is just 200mm long. It will therefore probably be necessary to extend this lead, depending on the relative positions of the FPS and the control box. We tested the unit with a lead length of 1.2m without any problems.

To extend the cable, you can sol-



**The GT-511C1R FPS is mounted on the rear of a blank wall-plate. You will need to cut a 16 x 20mm hole to accept the scanning lens. Once it's in place, the module can be secured to the rear of the wall-plate using silicone.**

der a 4-way rainbow cable or 4-way telephone cable to the FPS pads on the main PCB. The individual wires are simply pushed through the holes from the underside of the PCB and soldered on top side (ie, to the left of D1). The extension cable can then be connected to the JST-SH lead by first sliding short lengths of 2mm-diameter heatshrink tubing over the wires, then soldering the individual leads together. The heatshrink tubing is then slid over the solder joints and shrunk down with a hot-air gun.

Finally, the joins can be secured by sliding a length of 5mm-diameter heatshrink over the whole lot and shrinking it down.

Make sure that the JST-SH cabling is connected with the correct polarity. The black lead on the JST-SH plug is pin 1. The remaining white wires must be connected in the correct order to pins 2, 3 & 4 on the main PCB. Double-check this if using an extension cable, to ensure that the connections are still correct.

## Final assembly

Now for the final assembly. It's basically a matter of feeding the JST-SH plug and its lead through the corresponding case hole, then sitting the PCB in position inside the case so that it rests on the four integral standoffs at the corners. The PCB is then secured to these standoffs using No.4 self-tapping screws.

The next step is to produce and fit a front-panel label to the case lid. There are a couple of options here, the first being to print the downloaded PDF file onto clear overhead projector film (use film that's suitable for your printer).

### Datafelex/Datapol Labels

(1) For Dataflex labels, go to: www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_60&products_id=335
(2) For Datapol labels go to: www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_55&products_id=326

This label can then be attached to the inside of the lid using clear silicone sealant and the holes for the switches cut out with a sharp hobby knife (note: you will be able to see some of the "workings" inside the case with this panel).

Alternatively, you can print onto a synthetic Dataflex or Datapol sticky label (see panel) and attach that to the lid after cutting out the LCD hole. The switch holes can then be cut out.

Place the lid to one side after affixing the labels. It's attached to the case later, after the test and adjustment procedure has been completed.

## Mounting the FPS

In most cases, you will want to mount the FPS module on a standard blank wall switch-plate (see photos). You will need to cut a 16 x 20mm hole to accept the scanning lens and this should be carefully filed to size so that the module is a tight fit. Once it's in position, the FPS module can be secured in place using silicone sealant.

If the FPS isn't going to be wall-mounted, then it can be mounted in a zippy box.

## Testing

Now for the test procedure. First,

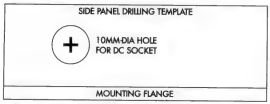



**Fig.3 (above): the drilling template for the righthand end panel of the case. A 10mm hole is required to provide access to the DC socket on the PCB.**

**Fig.4 (right): the full-size front-panel artwork. It can be copied or downloaded as a PDF file from the SILICON CHIP website and used as a drilling template for the switches. The PDF file can also be used to print a sticky label – see box panel.**

## Dealing With Security Errors

If the display shows **Serial No. Error**, this means that the FPS has been changed, either by a prospective intruder hoping to defeat the system or by someone authorised to replace the unit. In the latter case, the security number of the FPS will need to be reloaded in order to get the Fingerprint Access Controller working again.

That's done by pressing and holding down switch S5 inside the control unit. This will load the new FPS security number and the switch can be released when the LCD screen shows **Loading FPS Serial No.**

Alternatively, if the FPS has been replaced by an unauthorised person, then it would be wise to delete all enrolments after reloading the FPS serial number and start again.

An **Enrolment Tamper** indication on the display indicates that an enrolment has been made to the FPS using a different controller. Once again, it would be wise to delete all enrolments and start again. Table 2 summarises the security errors.

If the FPS back-lighting doesn't flash and the switches have no effect, the unit has probably halted due to some form of FPS tampering, as detailed in the main article. In that case, the control unit should first be powered down and then powered up again. It's then just a matter of checking if the unit is operating again and that access is possible when a valid fingerprint is scanned.

**Table 2: Security Errors**

| Security Error On LCD | What It Means |
|---|---|
| **Serial No. Error**<br>**Press Enter**<br>(Enter returns to the home screen, FPS blue LEDs are off) | The serial number of the connected FPS doesn't match the serial number stored in the control unit. If the FPS swap is legitimate, press S5 in the control unit to read and store the new serial number. If not, delete all enrolments in the new FPS and press S5, then re-enrol valid fingerprints. |
| **Enrolment Tamper**<br>**Press Enter**<br>(Enter returns to the home screen, FPS blue LEDs are off) | One or more enrolments have been made to the FPS using a different controller. Delete all enrolments and start again. |

check that the FPS module is unplugged, then apply power and adjust trimpot VR1 for optimum contrast on the LCD. That done, switch off, connect the FPS module and apply power again.

When the complete unit is powered up, it will automatically read and store the FPS module's unique serial number in the PIC microcontroller IC1's EEPROM (non-volatile memory). At the same time, the LCD module will display **Loading FPS Serial No.** for a short period before showing the normal home screen which displays **Fingerprint Security Access**.

Once the serial number has been loaded, the FPS should briefly flash its blue back-lighting LEDs once every second. If you then place a finger on the FPS sensor, the blue back-lighting LEDs should light continuously, indicating that a finger has been detected.

At this stage, no fingerprints will be stored in the database and so you will be greeted by an **Access Denied No Enrolments** message.

The next step is to check the switch functions on the switch PCB. As mentioned previously, these four switches (designated Menu, Return, Down and Up) allow for enrolments and other changes.

Each time the Menu button is pressed, the display should cycle between the **NewEnrol ID**, **Enrolled ID**, **Delete All IDs**, **Scan Resolution** and **Door Strike Time** menus. Check that this switch functions correctly, then check the operation of the Enter, Down and Up switches. Note that these latter three switches are only effective when menus are opened.

Once you have confirmed that everything is working correctly, fasten the lid in place using the four self-tapping screws supplied with the case.

### Entering enrolments

This unit is simple to set up and use. The first step is to enrol fingerprints into the FPS unit and that's done as follows:

- Press the Menu button to bring up **NewEnrol ID** menu – see Fig.5. The controller then checks the enrolments list and the first lowest ID number available will be shown. If the database is full, the LCD will display an **Enrolments Full** message. In that case, you would first need to delete an enrolled ID.
- Press the Up and Down buttons if you wish to select a different enrolment number to that shown. Note that any previously enrolled ID numbers will not be displayed.
- Press the Enter button to start the Enrolment process for the displayed ID. This involves taking three separate fingerprint scans which are then merged into the scanner's database.

During this process, you are first prompted to place your finger on the scanner (**Press Finger**) so that the first fingerprint "capture" can be made. You are then asked to remove the finger (**Remove Finger**) before being instructed to press the finger on the scanner again. This is then repeated once more, after which **Enrolled** will be displayed on the LCD to acknowledge the enrolment.

Note that the **Enrolled** message is only displayed for about one second, after which the unit returns to the **Fingerprint Security Access** message.

- Any errors during enrolment are shown on the LCD as **Enrolment Fail**, **Poor Fingerprint** or **Finger Off Error**. If that happens, the unit returns to the start of the enrolment and the process must be started all over again.

It's not unusual to have to make more than one attempt to achieve a successful enrolment. Note that a dry finger is not always readily recognised and it may be necessary to slightly moisten your finger before placing it on the scanner. In addition, try to place your finger in a similar position on the scanner each time during the enrolment process.

### Deleting enrolments

Deleting enrolments is straightforward. All you have to do is press the Menu button to bring up the **Enrolled ID** menu or the **Delete All IDs** menu and press the Enter button. If the **Enrolled ID** menu is selected, only the displayed enrolment ID will be deleted when the Enter button is pressed and

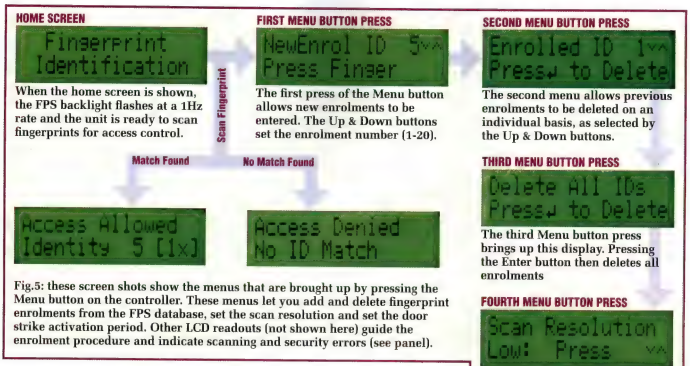



**Fig.5: these screen shots show the menus that are brought up by pressing the Menu button on the controller. These menus let you add and delete fingerprint enrolments from the FPS database, set the scan resolution and set the door strike activation period. Other LCD readouts (not shown here) guide the enrolment procedure and indicate scanning and security errors (see panel).**

this can be selected using the Up & Down buttons.

## Resolution & strike time

The remaining two menus, for **Scan Resolution** and **Door Strike Time** are just as easy to use. Just select the menu and press the Up and Down buttons to change the settings. As mentioned previously, you can set the scan resolution to either high or low, while the strike time can be set from 1-255s.

## Fingerprint access

Once the enrolments have been made, the unit is ready for use. When a finger is placed on the scanner and access is allowed, the LCD shows an "in brackets" guide listing how many times the user's fingerprint has been compared against the enrolments in the database (this is shown following the ID number). A **[1x]** display means that the fingerprint was successfully compared with the database on the first attempt.

Up to six complete fingerprint captures and comparisons with the database are allowed before it displays a **No ID Match** reading. When that happens, the user can remove and replace his finger on the scanner and try again.

Note that the low-resolution setting may give more reliable matches than the high-resolution setting. Note also that the FPS will identify a fingerprint that's rotated compared to the original enrolled version. In fact, the fingerprint can be rotated by up to 360° (Editor's note: we are not to sure why you would want to rotate your finger by up to 360° though).

## Installation

The electric door-strike is designed to replace the normal door catch of a standard door lock. It can be installed by chiselling out the door jamb to accommodate the solenoid and then securing it in place using countersink screws. The wiring is then run from the door-strike to CON2 in the control box.

The wiring polarity to the door strike is not important.

As stated previously, the FPS module would normally be fitted to a blank switch-plate. This assembly would then be mounted on the access side of the door, close to the door handle. Be sure to keep it well away from any 230VAC mains cabling or wall switches etc.

Be sure to waterproof the scanner if the unit is to be located outdoors. That can be done by mounting the switch-plate on a covered switch box and running a thin bead of silicone around the outside edge of the scanning lens. Don't get any silicone on the lens though, otherwise it won't work.

The control box can be mounted adjacent to the door-strike on a wall inside the secured area. Alternatively, if you want to be able to see the LCD when using the scanner, you could arrange to have the control unit mounted behind a smash-proof glass window, with the LCD facing outside.

On the other hand, if security isn't vital, the control box could be located with the scanner. However, it would be a good idea to remove the switch PCB to prevent the unauthorised addition of fingerprint enrolments.

## Bezel lamp

One option that you might like to consider is to mount a 12V bezel lamp on the wall-plate adjacent to the FPS module. This lamp can then be wired in parallel with the door-strike (ie, by connecting it to CON2), so that it lights whenever the door-strike is powered.

The lamp bezel can use either a filament bulb or a LED. **It must be wired via a 100mA fuse located in the control unit.** That way, if someone pulls the lamp bezel out and tries to activate the door strike by feeding 12V back down the lamp wires, the fuse will blow and prevent access. **SC**

**What's your DAB+ reception like? Spasmodic? Subject to spitting and dropouts? You need a decent antenna rather than rely on the nearly useless extendable whip antenna fitted to most DAB+ radios. This 5-element Yagi antenna is specifically designed for DAB+ radio and should markedly improve your reception. In some cases it could mean actually receiving DAB+ signals where there are now none!**

# Build this 5-Element Yagi Specifically For DAB+

## Digital Audio Broadcasting

By LEO SIMPSON

**Many people these days** have DAB+ radios but they are often disappointed in the reception, even though they may live quite close to the transmitters in Australia's capital cities.

They buy a DAB+ radio because they have been sold on the "clean, clear digital sound" that it is supposed to have. But often, the results are less than expected, mainly for two reasons.

First, virtually all DAB+ radios come with an extendable whip antenna which does double duty for FM and DAB+ reception. Truth is, these whip antennas are at best a compromise for either mode.

Nor do most DAB+ radios have an antenna socket into which you can plug an external antenna. So the average listener is stymied – even if they want to improve reception.

And the second reason why DAB+ sound quality is generally disappointing is the that digital data rate (ie, at the station) is simply too low for good quality sound.

This means that a station broadcasting on FM and DAB+ will typically sound much better on good old "steam-driven" FM stereo multiplex transmissions.

(And before any of our readers email

us about the "steam-driven" comment, think about it. FM transmitters are "steam-driven"; or at least, most of them are in Australia!)

Even so, a DAB+ radio fed with a good signal will always have a quiet background, no "spitting" and will sound quite clean to most ears.

So this article will describe how to build a good DAB+ antenna and also, tell you how to fit an antenna socket to your radio so you can feed the improved signal into it.

By the way, if you go on-line to see if you can buy a DAB+ antenna, you can't. As far as we can tell, they are simply not available. The closest you will come is a DAB antenna from the UK. Don't buy one of these as they are not cut to suit the DAB+ transmissions in Australia. UK DAB uses the band from 215 to 230MHz.

## Vertical polarisation

All of the DAB+ transmissions in Australia are vertically polarised. That means that any receiving antenna must also be vertically polarised. That brings about an important constraint about how the antenna is mounted on a metal mast, as we shall see shortly.

As with the FM antenna presented in last month's issue, this is a 5-element Yagi design but is half the size of the FM antenna because it operates at roughly twice the frequency.

All of the DAB+ transmissions in Australia's capital cities (Adelaide, Brisbane, Melbourne, Perth and Sydney) are in three bands: 202.928MHz (9A); 204.64MHz (9B) and 206.928MHz (9C). Canberra and Darwin have experimental transmissions centred on 211.648MHz (10B).

The Yagi antenna presented in this article is designed to cover all the DAB+ bands in Australia. It has a measured gain of about +12dB with respect to a whip antenna. However, that figure is with respect to a dipole which has a ground plane. Unfortunately, the whip antennas in DAB+ radios do not have adequate ground planes so their performance is even worse.

With good "line of sight" reception, a 5-element Yagi antenna like this should give reception at quite long distances from the transmitter, perhaps 100km or more. However, we have not tested this aspect. We can vouch for the gain figure though (as detailed later in this article).

## Tools you will need

Most enthusiasts will have all the tools needed for this project. You will need a hacksaw, electric drill and a vice. It would also help if you have a drill press but you can do without this.

Apart from an antenna clamp (U-bolt and V-block), no special hardware or fittings are required.

## Tube cutter

Last month we noted that a tube cutter is a very handy tool in an antenna project such as this. You end up with smooth square cuts with no swarf. We

## The "Digital Cliff"

Unlike analog broadcast radio (AM or FM) but very similar to digital TV, with DAB+ radio you have either got a signal, or you haven't. There's virtually no middle ground!

It's the dreaded Digital Cliff – the metaphor is that if you don't have enough signal (or, perhaps surprisingly, too much signal causing overload) digital radio or TV falls off the cliff and you get nothing.

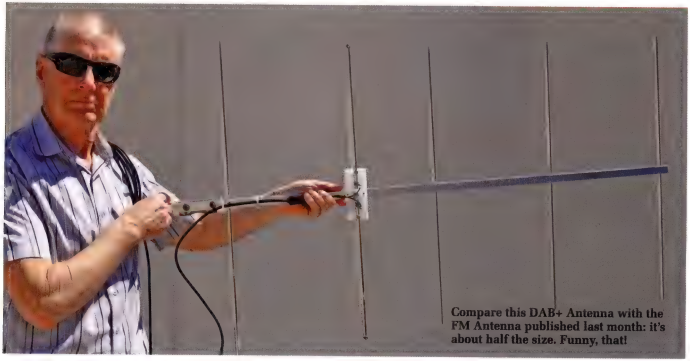
Of course, either digital radio or TV might be trying to tell you it's struggling, with continual dropouts and break-up when it's just on the point of teetering over the edge – most listeners or viewers would not tolerate this and turn off.

It's often found that weather can also push reception over the cliff.

The big advantage of this project is that the gain of the Yagi can lift your signal to the point where you get reliable levels; enough to give you good reception.

The other side of this is that DAB+ is currently transmitted only in the mainland capital cities – even those in close-by urban centres (Central Coast/Illawarra/Blue Mountains around Sydney and Geelong/Mornington Peninsular around Melbourne, for example) find DAB+ signal levels are just too low for reliable reception.

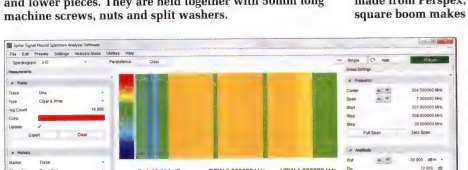
With 12dB of gain, we would expect this antenna will bring a lot more listeners into the DAB+ family!



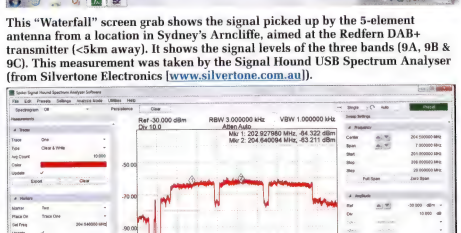
**Compare this DAB+ Antenna with the FM Antenna published last month: it's about half the size. Funny, that!**

The ends of the folded dipole are fabricated using 42mm lengths of aluminium tubing shaped to mate with the upper and lower pieces. They are held together with 50mm long machine screws, nuts and split washers.

The dipole insulator plate has wing nut terminals to connect 300Ω ribbon or a 300Ω-to-75Ω balun. The plate is made from Perspex, Lexan or other acrylic material. The square boom makes mounting easy.




This "Waterfall" screen grab shows the signal picked up by the 5-element antenna from a location in Sydney's Arncliffe, aimed at the Redfern DAB+ transmitter (<5km away). It shows the signal levels of the three bands (9A, 9B & 9C). This measurement was taken by the Signal Hound USB Spectrum Analyser (from Silvertone Electronics [www.silvertone.com.au]).




By comparison, this Spectrum Analyser display was taken with a vertical whip antenna adjusted to 368mm long (1/4 wavelength) and with a substantial ground plane. As you can see, the received signal level is about 12dB less than that received with the 5-element Yagi described here.

used a Bunnings product, the Haron Model STC330N. When using this cutter, it is important not to rush the job. Mark the position of the cut on the tube with an HB pencil and then position the blade of the cutter precisely on the mark, with the tube sitting between the rollers. Apply very light pressure with the knob of the cutter and then measure from the end of the tube to the blade of the cutter, to make sure you are cutting to the exact length you want (to be sure, to be sure!)

Actually, if you have not used one of these cutters before, do a couple of practice cuts on scrap plastic conduit, just to get the feel of the whole procedure.

You are also likely to find that because the tube is very smooth and quite small in diameter, it is hard to get a grip on it as the cut deepens. Gripping the tube with a rubber kitchen glove makes it a lot easier.

## Buying the alumimium

For convenience we purchased the 10mm round aluminium tubing and 19mm square aluminium tube from the local Bunnings warehouse.

They stock the 19mm square tube in 3-metre lengths and the 10mm tubing in 1-metre lengths. So we purchased six 1-metre lengths of the 10mm tube and one 3-metre length of the 19mm tube. Total cost: $33.98.

You might be able to purchase your aluminium from a nearby metal supplier and in that case, they might also cut it to the various lengths you will need (perhaps for a small extra charge?).

One drawback of buying tube from Bunnings is that every item you pur-

chase has an adhesive label attached which is obviously meant to last for longer than the life of the product! At least, it seems that way when you are trying to remove seven labels – it took ages! At least I ended with highly polished tubes!

## Screws & nuts

After a few years' exposure to the elements, many antennas are in a poor state. Aluminium may not "rust" but it does oxidise, particularly in seaside areas or in metropolitan areas where there is a lot of industrial fallout.

Corrosion will also be a lot worse if you don't use the right screws and nuts. We strongly recommend the use of stainless steel screws, nuts and washers throughout, whether for machine screws or self-tappers. They do cost a little more but they last indefinitely. You will find a good array of stainless steel screws available from ships' chandlers.

Don't, on any account, use brass screws. When used to attach aluminium elements these will corrode away almost before your eyes. Nor do we recommend galvanised, bright

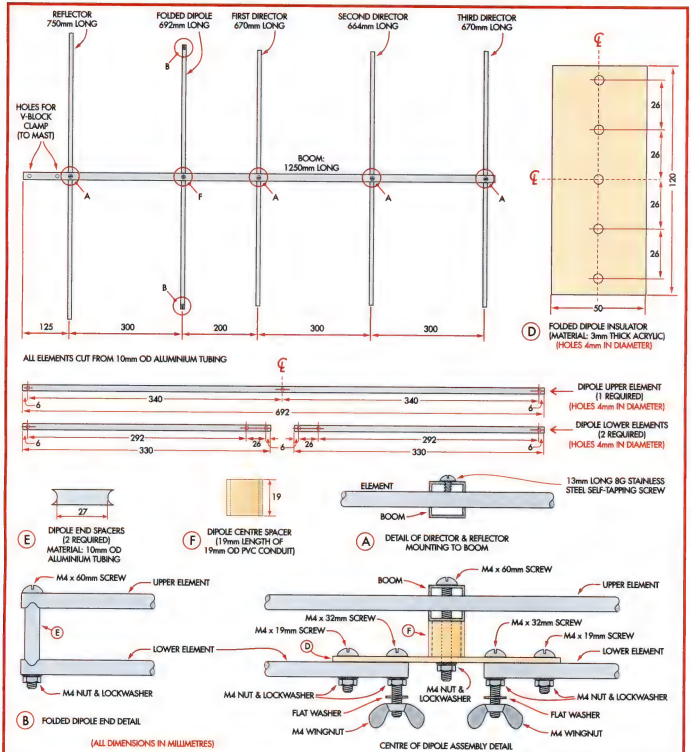
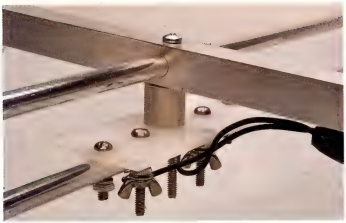
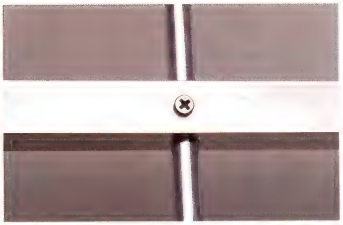



**Fig.1: this diagram shows all the details of the 5-element antenna. At top is a plan view while the other diagrams show hardware and element mounting details.**



This topside view of the antenna shows how the folded dipole is attached to the square boom. Note the short section of PVC conduit which acts as a spacer between the underside of the boom and the dipole insulator plate. Whitworth or other machine screws hold it all together.



The reflector and director elements are attached to the boom using self-tapping screws. Ideally, all screws, nuts and washers should be stainless steel to avoid corrosion. To check that screws are stainless, take a magnet with you when buying them. If they attract, they ain't stainless!

zinc or cadmium-plated steel screws.

In seaside areas these can be visibly corroded with just a few days' exposure.

In rural areas, away from the sea or city pollution, you can probably get away with galvanised screws but the antenna will last longer if you paint it.

## Starting work

Constructing this antenna is quite straightforward. If you have all the materials available you can probably do it in a couple of afternoons.

Fig.1 shows all the details of the 5-element antenna. It shows the dimensions of all the elements and the various hardware bits you will have to make to assemble the antenna. At top is a plan view showing the length of all five elements and their spacing along the boom.

Before you start, make sure you have obtained all the aluminium and hardware listed in the Parts List. You will be frustrated if you get half-way through and find you can't progress further because you lack screws or some other item. Get 'em all before you start.

You need to cut the 19mm square tube (the boom) to length and then mark it for drilling and this is where it is quite easy to make mistakes.

If you are experienced in metalwork and have access to a set of vee-blocks and a drill press, you could substitute 25mm diameter tubing for the boom. In fact, you could use 25mm stainless steel round tubing which is readily

## Current DAB+ Transmission Sites around Australia (*as at 5 October 2015*)

| City | Transmitter Location |
|---|---|
| Adelaide | TXA Crafers Site Tower 115 Mount Lofty Summit Road CRAFERS |
| Brisbane | TXA T-Site Tower 445 Sir Samuel Griffith Drive MOUNT COOT-THA |
| Brisbane | Broadcast/Comms Tower Digital Distribution Australia Site Mount Mee Rd MOUNT MEE |
| Melbourne | TXA Ornata Road Site Tower 12 Ornata Road MOUNT DANDENONG |
| Melbourne | Broadcast/Comms Monopole Pioneer Concrete Site 213 Boundary St PORT MELBOURNE |
| Melbourne | Broadcast/Comms Tower Roof 101 Collins Street MELBOURNE |
| Melbourne | Crown Castle Site Bald Hill off Swans Rd DARLEY |
| Melbourne | Tower Broadcast Australia Site Eyre Road MOUNT DANDENONG |
| Perth | Crown Castle Site Cnr Mulgrave Loop and Bergen Way MINDARIE |
| Perth | Central Park 152 to 158 St Georges Terrace PERTH |
| Perth | TXA Carmel Site 255 Welshpool Road East CARMEL |
| Sydney | TXA Artarmon Site Tower 192-196 Hampden Road ARTARMON |
| Sydney | TXA Willoughby Site Tower 15 Richmond Avenue WILLOUGHBY |
| Sydney | Broadcast/Comms Tower Sydney Tower Westfield Centrepoint 100 Market Street SYDNEY |
| Sydney | Broadcast/Comms Monopole Crown Castle Site Plateau Park off Blandford St COLLAROY PLATEAU |
| Sydney | Broadcast/Comms (Optus) Tower Sydney Water Board Site off Plateau Rd BILGOLA PLATEAU |
| Sydney | Broadcast/Comms Tower Rooftop Tower 1 GCA Building 1 Lawson Square REDFERN |
| Sydney | Broadcast Monopole Aust Radio Network Site 754-768 Hawkesbury Rd HAWKESBURY HEIGHTS |
| Sydney | Crown Castle Site Badgelly Hill off Badgally Rd GREGORY HILLS |

Canberra and Darwin currently have limited "experimental" transmissions *(source: ACMA)*

available from plumbing supply stores but it is expensive and not easy to work.

Centre-punch the boom for all holes prior to drilling. The boom is 1250mm long and the total of the element spacings along the boom is 1100mm – see the plan diagram on Fig.1. Mark the hole centre position for the reflector element first, 125mm from one end of the boom, and then work your way along.

If you have a drill press which lets you drill all the element holes square through the boom you are fortunate. If not, mark the hole centre positions on both sides of the boom and drill from both sides. If you don't get the element holes lined up properly, you will have the elements skew-whiff.

A few words of advice on drilling is appropriate here. Drilling in thin wall aluminium tubing can be a problem and many people tend to end up with holes that are more triangular than round. The way around this problem is to drill all the large holes (ie, all 10mm holes) under size and then ream them out to the correct size using a tapered reamer.

Don't drill the larger diameters with too high a speed otherwise there may be a tendency to produce "triangular" holes.

If you have a bench drill which allows you to set slower drilling speeds, so much the better. Either way, it is best to drill the element holes to 10mm and then slightly increase each hole with a tapered reamer so that each element is held firmly in the boom.

## Reaming larger holes

Be careful when reaming holes out though because it is quite easy to get carried away and then end up with holes that are oversize. Use a scrap piece of 10mm tubing to test when the holes specified at 10mm are the correct size.

Each director element and the reflector is held in the boom with a self-tapping screw, as shown in diagram A of Fig.1. Drill a 3mm hole at the centre point of each element but only through one side. Don't mount the elements on the boom yet though because the dipole should be assembled and mounted on the boom first.

You need to keep a mental image of how the finished antenna will appear. All the directors, the folded dipole and the reflector will all be vertical (ie, perpendicular) but the holes for the clamp, at the reflector end of the boom, will be horizontal.

Confused? Take another look at the photos of the finished antenna.

Now cut the 10mm diameter tubing for the director, three reflectors and parts for the dipole. Remember the old adage about "measure twice and cut once". It's hard to lengthen elements that are too short. Note that two of the directors are the same length, ie, 670mm while the other is 664mm.

## Making the dipole

The folded dipole is made from five pieces of 10mm aluminium tubing, three long and two short. The detail of its assembly can be seen from the diagram at the bottom of Fig.1. The two short tubes, shown as diagram E on Fig.1, are cut and shaped so that they key in with the top and bottom elements of the dipole. Further detail is shown in the accompanying photos.

The top and bottom pieces of the dipole are held at each end with a 60mm long M4 screw (or 3/16-inch Whitworth), together with a nut and lock washer. At the centre, the lower halves of the dipole are terminated on an insulating plate (shown in diagram D of Fig.1). This plate is made of 3mm acrylic (Perspex or Lexan). The dipole halves are each secured to the insulating plate with a 19mm long M4 (or 3/16-inch Whitworth) screw, nut and lock-washer.

Terminals for the dipole are provided with two 32mm long M4 or 3/16-inch Whitworth screws, each fitted with a nut and lock-washer plus a wing nut and flat washer.

The insulating plate is secured to and spaced off the main boom via a 19mm length of 19mm PVC conduit, shown as a "folded dipole spacer" in diagram F of Fig.1.

The top piece of the dipole is secured to the boom with a 60mm long 3/16-inch Whitworth or M4 screw, nut and lock-washer

The details of the dipole insulating plate and fixing to the boom can be seen in the accompanying photos. Note that while we used white Perspex, you could use a piece of polycarbonate if that is what you have on hand. However, note our remarks on painting, later in this article.

By this time the antenna looks just about complete. You need to add the antenna clamp, to enable it to be attached to the mast. This *must* be mounted at the end of the boom (ie, behind the reflector) and oriented to allow the elements to sit vertically.

You will also need a 300Ω-to-75Ω balun to match it to 75Ω coax cable. You *could* use 300Ω ribbon if you wish and omit the balun but to obtain the most interference-free signal, we recommend coax cable for your installation.

Unfortunately, many antenna clamps are sold with a cadmium-plated and passivated finish (which look like a "gold" finish). This is barely adequate for inland areas but rusts quickly in sea air. We may seem to be paranoid about corrosion but since the SILICON CHIP editorial offices are only a kilometre or so from the seaside we are very aware of just how quickly metal hardware can rust and corrode.

## Parts List – DAB+ Antenna

**Aluminium**

1.25 metres of 19mm square tubing with 1.8mm wall thickness
4.5 metres of 10mm diameter tubing with 1mm wall thickness

**Hardware**

1 120 x 40 x 3mm white Perspex
1 stainless steel or galvanised U-bolt and V-clamp to suit mast
4 8G x 13mm self-tapping screws
3 M4 x 60mm or 3/16in Whitworth screw (round head)
2 M4 x 32mm or 3/16in Whitworth screws (round head)
2 M4 x 19mm or 3/16in Whitworth screws (round head)
7 M4 or 3/16in nuts
2 M4 or 3/16in wing nuts
7 M4 or 3/16in lock washers
2 M4 or 3/16in flat washers
Note: all screws, washers and nuts should be AS316-grade stainless steel
1 19mm long spacer cut from 19mm conduit or similar

**Miscellaneous** (sizes/lengths to suit)

Mast and wall mounts or barge-board mount (hockey stick style)
300Ω to-75Ω in-line balun (Jaycar Cat LT-3028 plus matching F-connector)
Quality 75Ω coax cable (Jaycar WB-2006/9, Hills SSC32 or equivalent)
Plastic cable ties
Silicone sealant

**The V-block/U-bolt clamp should ideally be stainless steel or at worst hot-dip galvanised (don't use Cadmium-plated [or "passivated"] steel – you can see them rust before your eyes!). It must mount between the reflector (seen here on the right) and the end of the boom, so that the mast doesn't interfere too much with signal. Note the orientation – it mounts so that the elements are vertical when the clamp is attached to the mast.**

If you can, buy U-bolts and clamps that are stainless steel, as used for car exhaust systems (or boat fittings), as these will last a lot longer. At minimum, choose hot-dip galvanised.

Be aware that zinc "plated" fittings are not as rust resistant as galvanised types. Zinc-plated fittings have a smooth bright appearance while hot-dip galvanising is unmistakable – it has quite a rough appearance.

We also suggest that the ends of all the elements and the boom be stopped up with silicone sealant. This will stop them from whistling in the wind. (Commercial antenna manufacturers tend to squash the ends flat for this purpose).

Better still, you can buy Delrin plugs to suit the square aluminium tubing. These look neater.

If you live in an area where corrosion is a problem, it is also a good idea to paint your antenna. If nothing else, the dipole insulating plate should be painted as acrylic material does deteriorate in sunlight (ie, UV).

We suggest you leave the antenna for a month or so to weather it and then paint it with an etch primer. Finish it with an aluminium loaded paint.

## Installation

When you have finished your antenna you need to carefully consider its installation. There is no point in going to a lot of trouble making it if you don't install it properly.

Try to install your new antenna well away from existing TV antennas as these can have quite a serious effect on the performance.

Similarly, nearby metal guttering, electric cabling, metal roofing or sarking (ie, reflective insulation such as Sisalation) can have a bad effect on antenna performance.

And don't forget the effect of a hot water tank which may be lurking just beneath the roof tiles.

If you live on a busy street, try to install your antenna as far away as possible from the traffic side of your house. That will help minimise ignition noise from passing traffic.

Finally, install the antenna as high as possible above the roof and guttering. If that is a problem, try to install

# Connecting your DAB+ Antenna

OK, so you've finished your DAB+ Yagi and now you're ready to connect it to your receiver. Most DAB+ tuners do have an antenna input socket, so that makes it easy.

But the vast majority of DAB+ radios (especially the smaller ones and virtually all portables) are not equipped with any form of antenna input, apart from the whip antenna.

So how can you connect an external antenna?

## What are the connection options?

The antenna (and the coax lead in) require a connection to both the antenna input and earth. And with very few exceptions, there is nowhere on the outside of the case to get an earth connection.

So you need to install a socket on the back of the receiver which the cable from the antenna could be plugged into.

## Fitting a socket

Open up your receiver and find an appropriate place to mount a socket. While the back panel of our receiver is quite spartan, inside the possible locations are limited by existing fittings and hardware.

Two main points to watch when choosing a location are:

(a) mount it as close to the receiver's input terminals as possible to keep your input wires as short as possible (we are using ordinary hookup wire, not coax); and

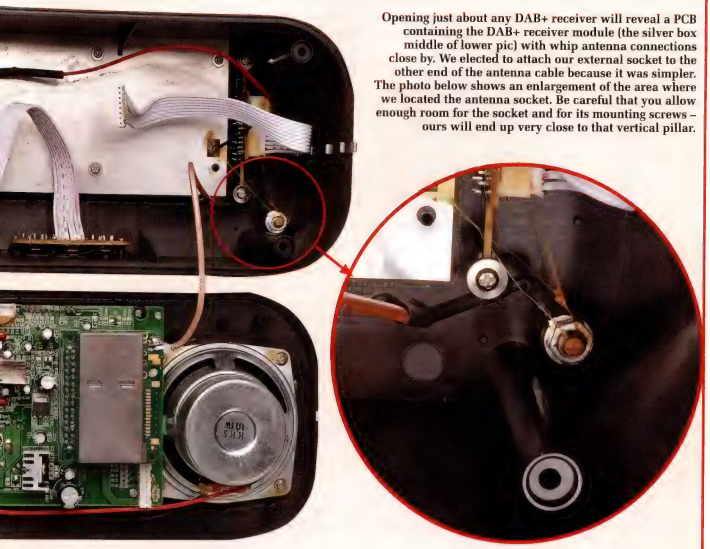
(b) check inside the receiver to make sure the mounting position will not foul any internal hardware – and that you have enough room to fit any washers/nuts to hold the sockets in place.

The type of socket is up to you – those receivers which do have input sockets often use standard 3.5mm "audio" types because they're nice and small. However, we elected to use a standard "Belling Lee" socket (sometimes called a "PAL" socket) as used on TV antennas, mainly because it seemed appropriate to use the "normal" plug/socket for 75Ω coax.

Fit the socket first, then wire the connections to the receiver. We chose to connect to the bottom end of the whip antenna mounting rather than the receiver's PCB because it was the shorter connection; the "braid" connection from the socket connected to a solder lug under the same self-tapping screw which connected the receiver's ground plane.

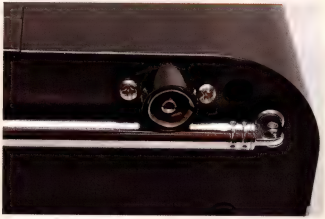
We couldn't find a solder lug large enough to fit under the antenna mounting, so effectively made one by winding a double loop of hookup wire about 7mm in diameter and applying solder to that, making it rigid. We were fortunate when we removed the nut holding the whip antenna in place, there was plenty of "meat" left on the thread to allow our "solder lug" to fit on as well.

Our photographs explain all this in detail.



Opening just about any DAB+ receiver will reveal a PCB containing the DAB+ receiver module (the silver box middle of lower pic) with whip antenna connections close by. We elected to attach our external socket to the other end of the antenna cable because it was simpler. The photo below shows an enlargement of the area where we located the antenna socket. Be careful that you allow enough room for the socket and for its mounting screws – ours will end up very close to that vertical pillar.

And here is that antenna socket, wired into the mounting hardware for the whip antenna (the blue wire) and to a solder lug connecting to the ground plane and the antenna wire braid (green wire). We used ordinary hookup wire to make the connections.



Finally, here is what the antenna socket looks from the outside. We used a standard Belling-Lee connector, just as you would find used on the antenna socket on most TV sets. A matching plug was wired to the end of the coax cable coming from the new DAB+ Antenna.

the antenna so that it is at least a half wavelength away from the nearest metallic object such as guttering or roofing. This means a distance of about 750mm away from guttering.

Take care when installing the antenna. Safe working with ladders is particularly important. Take your time and don't take risks. You don't want to end up in hospital.

Line up the antenna so that it is aimed at the closest DAB+ transmitter. As you can see from the table on page 40, they can be fairly widely separated but all contain the same stations (in a geographic area) so simply aim at the one that is either closest to you, or the one that gives you best performance (eg, minimal errors shown on the DAB+ station readout).

More often than not, they will be the same transmitter.

## Choosing coax cable

You probably know that there is a wide range of prices for coaxial cable, ranging from cents per metre to dollars per metre. What's the difference and why is it important? When it comes to coax quality, price is usually a pretty good guide.

Apart from the coax impedance (you want 75Ω), the main criteria you look for is attenuation, or loss. Unfortunately, all coax is lossy – this means that even if you get the last microvolt of signal from your antenna, depending on the quality of the coax lead, some of it/a lot of it/most of it can be lost on the trip to your receiver.

As a matter of interest, when we were checking out the performance of this antenna, we were getting diabolically bad results. It turned out that the length of coax cable was crook – really crook!

Swapping to a new length of cable gave us the results we were expecting (actually better – but we would say that, wouldn't we!).

Cheaper coax has a solid plastic dielectric, mid-range has an extruded pattern which is mostly air (hence "air-core"); the best domestic coax has "foam core" dielectric, (which has minimum loss) and the outer conductor is not only pretty tightly woven (for minimum loss) it also has one or more levels of aluminium foil surrounding the copper mesh (for minimum loss AND to minimise interference!)

Attenuation is expressed in dB/100m and increases as frequency increases. Because we're not talking super high frequencies (~200MHz) you can be a bit less fussy in selecting coax.

But really, if you're making this antenna because you need all the signal you can get to avoid the digital cliff – and especially if the length of coax lead-in needs to be relatively long – buy the best coax you can afford, within reason.

When the antenna is mounted on its mast, make sure the coax is firmly secured to that mast (and to the antenna boom) with cable ties, otherwise the cable can flap around in the wind.

There is nothing more annoying than lying in bed late at night and listening to the cable slapping against the mast!

Cable ties are cheap: use them!

## Performance

Before conducting any measurements, we hooked the Yagi up to a "generic" DAB+ radio in a known very poor signal area – Narrabeen, in Sydney's northern beaches area.

In fact, until recently there was *no* DAB+ in Narrabeen. The "new" Collaroy Plateau transmitter has alleviated this to some extent but our test location is deep under the plateau escarpment – anything but line-of-sight.

What a difference!

The Yagi pulled in quite a few stations which were simply not there before; of those that were, signal levels were much improved.

Then, to prove the performance of the DAB+ Yagi, we took a number of spectra using the Signal Hound Spectrum Analyser (as reviewed in the October 2014 [siliconchip.com.au/Issue/2014/October/Signal+Hound+USB-SA44B+Spectrum+Analyser] and June 2015 [siliconchip.com.au/Issue/2015/June/SPIKE%3A+Improved+Software+For+The+Signal+Hound] issues).

Two of these graphs are shown on page 38 – they confirmed our first tests and demonstrate that the new antenna has a gain of around 12dB with respect to a whip antenna – that's pretty good and well worth the investment! SC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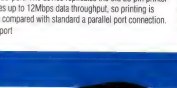

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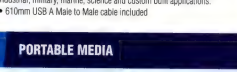

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Control 2 computers with a single computer screen, keyboard, and mouse.

- High video resolution support (up to VGA Resolution: 1920 x 1440 (Digital); 2048 x 1536 (Analogue)
- Features QuickSwitch button on a 1.5m wired remote control
- Supports wireless USB keyboard / mouse, USB flash drive and other USB devices

WC-7590

DOUBLE POINTS

FROM $11.95

## Monitor Cables

A variety of DVI, VGA and XVGA cables to suit your unique applications.

**1.8M VGA DB15HD MALE TO DB15HD FEMALE** WC-7500 **$11.95**
**1.8M VGA DB15HD MALE TO DB15HD MALE** WC-7582 **$11.95**
**2.0M DVI TO DVI** WC-7590 **$29.95**
**5M XVGA DB15HD MALE TO DB15HD MALE** WC-7588 **$39.95**
**10M XVGA DB15HD MALE TO DB15HD MALE** WQ-7258 **$49.95**

## TELECOMS

$7.95

## RJ12 6P/4C Wall Phone Bracket YT-6062

Designed to allow easy installation of telephones which have standard US modular wall mountings.

- Fits standard Australian electrical switch plate
- ACA approved

**RJ12 6P/4C LEADS SOLD SEPARATELY:**

**5.0M** YT-6049 **$7.95**
**10M** YT-6041 **$11.95**
**15M** YT-6043 **$14.95**

**NERD PERKS OFFER**
**BUY 2 FOR $23.90**
**SAVE UP TO $10**

## Cat 5 UTP Splitter

YT-6090

**RRP $16.95**

Save time, money and space! Usually used in pairs, this UTP splitter enables two different devices to share the same Cat5 cable.

*NOTE: Cannot be used to run two computers from one network and not suitable for gigabit networks.*

$16.95

YT-6091

## ADSL Filters

If you have ADSL Internet Connection, you'll need a compatible filter to keep unwanted noise from the phone or fax line.

**ADSL2+ IN-LINE FILTER** YT-6091 **$16.95**
*Available in AU only.*

**ADSL SPLITTER FILTER** YT-7152 **$16.90**
*Available in NZ only.*

# DOUBLE POINTS FOR NERD PERKS CARD HOLDERS ON THESE UNINTERRUPTIBLE POWER SUPPLIES*

**Valid for purchase of MP-5224, MP-5201, MP-5207 or MP-5212.*

Protect your valuable setup with our value-for-money Uninterruptible Power Supplies. Keep your systems running long enough to save critical data when the mains power fails.

| | MP-5224 | MP-5201 | MP-5207 | MP-5212 |
|---|---|---|---|---|
| **Features** | Line interactive, economical model | Line interactive, desktop model | Line interactive, smart LCD desktop model | On-line, smart LCD rack mountable (2U height) |
| **Load Rating** | 600VA, 300W | 650VA, 360W | 1500VA, 900W | 1000VA, 700W |
| **Internal SLA Battery** | 12V/7AH x1 | 12V/7AH x1 | 12V/9AH x2 | 12V/7AH x3 |
| **Output Waveform** | Modified Sine Wave | Modified Sine Wave | Modified Sine Wave | Pure Sine Wave |
| **Transfer Time** | <10 ms | <10 ms | <10 ms | Instant |
| **Power Outlets** | 6 x AUS (3 bypass, 3 mains) | 2 x AUS mains | 2 x AUS mains | 6 x IEC |
| **Backup Time (Typical)** | 31 mins / 11 mins / 4.5 mins | 25 mins / 9 mins / 5 mins | 94 mins / 49 mins / 31 mins | 95 mins / 47 mins / 32 mins |

DOUBLE POINTS

MP-5224 $129

DOUBLE POINTS

MP-5212 $449

DOUBLE POINTS

MP-5201 $99.95

DOUBLE POINTS

MP-5207 $319

*Limited Stock. Available in store only.*

## RACK CABINETS AND ACCESSORIES

## 19" Rack Mount Cabinets

Jaycar's 19" rack mount cabinets are ideal for IT or phone system installations, studios and PA systems, with a size and configuration to suit your application. These cabinets are solid steel powder coated to provide high strength and rigidity under load and are packed flat for convenient transport. Coupled with our wide range of accessories and options, these 19" rack mount hardware are value for money and offer you outstanding features found on more expensive units. Unbeatable value!

**TECH TIP! SAVE TIME & MONEY**

Jaycar also stocks highly practical and value-for-money network installation and troubleshooting testers. *See our website or ask us now.*

FROM $59.95 SAVE UP TO $30

HB-5125

### Equipment Cabinet
**ALUMINIUM FRONT PANEL**

**1U** HB-5120
**WAS $69.95 NOW $59.95 SAVE $10**

**2U** HB-5125
**WAS $109 NOW $89 SAVE $20**

**3U** HB-5130
**WAS $129 NOW $99 SAVE $30**

FROM $139 SAVE UP TO $40

HB-5170

### Fixed Frame
**CLEAR TEMPERED GLASS DOOR**

**6U** HB-5170
**WAS $159 NOW $139 SAVE $20**

**1 2U** HB-5174
**WAS $229 NOW $189 SAVE $40**

FROM $199 SAVE UP TO $50

HB-5182

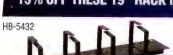
### Swing Frame
**CLEAR TEMPERED GLASS DOOR**

**6U** HB-5180
**WAS $229 NOW $199 SAVE $30**

**12U** HB-5182
**WAS $299 NOW $249 SAVE $50**

## 15% OFF THESE 19" RACK MOUNT ACCESSORIES FOR NERD PERKS CARD HOLDERS

HB-5432



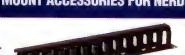
FROM $24.95

### Rack Cable Supports

Take the pain out of wiring and fault-finding rack cabinets. These high quality supports keep your cables organised and neat, and provides strain relief at the same time.

**1U** HB-5430 **$24.95**

**2U** HB-5432 **$29.95**



$29.95

### Patch Lead Management Panel

HB-5434

1U size, keeps all your patch leads under control.

HB-5420

FROM $10.50

### Blank Panels

Black powder coated panels for filling in unused space or configuring to your own requirements. Mount hardware included.

**1U BLANK PANEL** HB-5420 **$10.50**

**2U BLANK PANEL** HB-5422 **$12.95**

**2U BLANK VENTED** HB-5424 **$18.95**

**1U BLANK VENTED** HB-5426 **$27.95**

HB-5454

FROM $49

### Rack Shelves

Ideal for equipment that you want to include in your 19" rack but doesn't have rack-mounting ears. Each shelf is punched with ample slots for ventilation and takes loads of up to 20kg.

**1U FIXED SHELF** HB-5452 **$49**

**2U FIXED SHELF** HB-5454 **$69**

**1U SLIDING SHELF** HB-5450 **$99.95**

YN-8046

FROM $49.95

### Cat 5/6 24-Port Patch Panels

Sleek attractive looking rack mount 24 port patch panel with a hard metal exterior. Numbered ports and a labelling area for each port.

**1U, SUITS CAT5E** YN-8046 **$49.95**

**1U, SUITS CAT6** YN-8048 **$69.95**

$69.95

### 6-Way Power Distribution Unit

MS-4094

Power up to six 240VAC components in your rack setup. Surge/overload protected and fits any standard 19" rack. Includes 1.6m power lead.

- 1U rack space

## HANDY TOOLS FOR NETWORK INSTALLERS

$22.95

### Cat5 Adjustable Punch-Down Tool

TH-1740

Designed for seating wire into terminal blocks and has an adjustable internal impact mechanism. Supplied with 88 blade. 152mm long.

**ALSO AVAILABLE:**

**110 REVERSIBLE KRONE BLADE TO SUIT** TH-1743 **$17.95**

$19.95

### 6P/8P Modular Crimp Tool

TH-1935

This tool will crimp 6P2C, 6P4C-RJ11, 6P6C-RJ12 and 8P-RJ45 plugs. Also cuts and strips the cable.

# NEW RANGE OF DUINOTECH! 100% ARDUINO® COMPATIBLE.

## DOUBLE POINTS FOR NERD PERKS CARD HOLDERS

$89.95

### Arduino® Experimenters Kit
XC-4262

Learn about the exciting new world of Arduino® with these easy to build projects. From flashing an LED to moving things with a servo. Complete with instructions and a supporting web page and software examples.

- No soldering required

NEW

$7.95

### Arduino® Compatible Mini Prototype Board Shield
XC-4480

Drop this shield onto your Arduino® for prototyping small circuits. Solder-pads and a small breadboard is included which can be stuck to the top of the shield with the included tape.

- Fully compatible with Arduino®, Duinotech LEONARDO, Duinotech Classic

NEW

$9.95

### Arduino® Compatible 2.4GHz Wireless Transceiver Module
XC-4508

This module allows communication on the license free ISM band. Despite its diminutive size, it supports on-air data rates of up to 2Mbps. No external components are required (other than your Duino').

NEW

$19.95

### Solderless Breadboard
**WITH POWER SUPPLY** PB-8819

Ideal for circuit board prototyping and Arduino® projects. The power module can be powered from either a 12V plug pack or from 5V using the micro USB socket with a switchable output between 3V and 5V DC.

- 1 x Solderless Breadboard with 830 Points
- 1 x Power Supply Module
- 64 mixed jumper wires of different lengths and colours

## GO ONLINE OR IN-STORE TO SEE OUR EXTENSIVE RANGE!

$129

### Deluxe Modules Package
XC-4288

Get more savings by purchasing this 37 modules-in-1 pack. Includes commonly used sensors and modules for duinotech and Arduino®: joystick, magnetic, temperature, IR, LED and more.

NEW

$14.95

### Arduino® Compatible Ethernet Interface Module
XC-4436

Contains all the circuitry required to implement a complete Ethernet interface. Use this with your latest DuinoTECH project to send and receive email or host it's on website!

NEW

$19.95

### Arduino® Compatible Bluetooth® Module
XC-4510

Connected via the serial pins, and to your computer via Bluetooth®, this module creates a seamless serial-port link between you and your Duino' PLUS you can use it to communicate with your Bluetooth®-enabled Smartphone.

- 28(W) x 13(L) x 8(H)mm

NEW

$19.95

### Arduino® Compatible RF Transceiver Module
XC-4522

This module adds a versatile 433MHz radio to your Duinotech project allowing two-way wireless communication between Duinotechs. Controlled via SPI. Prewritten libraries available.

- Includes antenna
- 32(W) x 19(L) x 19(H)mm (Excluding antenna)

## ARDUINO® ESSENTIALS

$3.50

### Stackable Header Set
HM-3207

The perfect accessory to the ProtoShields and vero type boards when connecting to your Arduino® compatible project.

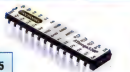
- 1 x 10-pin
- 2 x 8-pin
- 1 x 6-pin
- 1 x 2x3-pin (for ICSP)

NEW

$9.95

### Jumper Lead Assortment Kit - 90 Pieces
WC-6029

Jumper lead set for use in Arduino® projects, school experiments and other hobbyist activities. A kit of 90 pieces measuring 220mm in length and 2mm in width.



$12.95

### ATmega328P Microcontroller
ZZ-8726

An Atmel AVR ATmega328P microcontroller to build customised Arduino® compatible projects. Includes 16MHz crystal oscillator.

- Pre-installed Arduino® Uno bootloader

$26.95

### 4-Channel PoE Midspan Injector
XC-4254

Power up to four EtherMega's (XC-4256) or EtherTen's (XC-4216) with DC from a low cost plugpack across your home or office network cables. It isolates and powers the correct wires automatically.

FROM $12.95

PB-8814

### Solderless Breadboards
Three sizes of breadboards to suit all your project needs.

**300 TERMINAL HOLES** PB-8832 **$12.95**

**640 TERMINAL HOLES** PB-8814 **$19.95**

**1280 TERMINAL HOLES** PB-8816 **$43.95**

$16.95

### Resistor Pack 300-Pieces
RR-0680

This assorted pack contains 5 of virtually each value from 10Ω to 1MΩ.

- 0.5W 1% mini size metal film

*See website for full contents.*

$29.95

### LED Pack 100-Pieces
ZD-1694

This assorted pack contains 3mm and 5mm LEDs of mixed colours. Even includes 10 x 5mm mounting hardware FREE! *See website for full contents.*

- Red, green, yellow, orange LEDs

$34.95

### Light Duty Hook-up Wire Pack - 8 colours
WH-3009

Quality tinned hook-up wire on plastic spools. 8 rolls included, each roll a different colour.

- 25m on each roll

# SHIELDS AND MODULES

NEW

$9.95

## Arduino® Compatible Obstacle Avoidance Module
XC-4524

An inexpensive solution for an IR obstacle avoidance sensor, perfect for robotic projects with easy interface with Arduino® & compatible boards.

- Adjustable frequency and intensity
- 4 pin header
- 42(L) x 27(W) x 18(H)mm

$5.95

NEW

## Arduino® Compatible PIR Motion Detector Module
XC-4444

A pyroelectric infrared PIR motion sensor is a handy addition to any Arduino® project. Wide operating range and delay times changeable. A must for any security application.

- 32(L) x 24(W) x 25(H)mm

$29.95

NEW

## Arduino® Compatible Ultraviolet Sensor Module XC-4518

Measure the UV light and adjust the output voltage depending on the UV intensity. This is a valuable addition for all the weather station projects or in any places which require stable and accurate measurement of UV light.

- Response wavelength 200-370nm
- 43(L) x 13(W) x 8(H)mm

PCDUINO

$89.95

## PcDuino Nano V3.0 XC-4352

This version of the pcDuino is substantially smaller than its brother by omitting the Wi-Fi module. Wired Ethernet is included at full 1GPS speed.

- 95(L) x 55(W) x 17(D)mm

NEW

$4.95

## Arduino® Compatible Ultraviolet Sensor Module
XC-4512

This will measure the UV light and adjust the output voltage depending on the UV intensity. A valuable addition for all the weather station projects which require stable and accurate measurement of UV light.

- 43(L) x 13(W) x 8(H)mm

NEW

$7.95

## Arduino® Compatible DC-DC BOOST Module
XC-4514

Accepts any voltage from 3-34VDC, and outputs any higher voltage from 4-35VDC. Use it to run higher voltages from your lower supply. (ie. run 12V devices from a 5V supply)

- Maximum output current 2.5A
- 49(L) x 26(W) x 12(H)mm

NEW

$14.95

## Arduino® Compatible Stepper Motor Controller Module
XC-4492

Allows full control of two DC Motors or one stepper-motor. Suited to drive two-motor robot kits such as our KR-3130 or KR-3132. An on-board 5V regulator can be used to power your project.

- Motor voltage: 3-30VDC
- Requires six digital inputs
- 69(W) x 56(D) x 36(H)mm

DOUBLE POINTS

$119

## PcDuino V3.0 with Wi-Fi XC-4350

The latest version of the pcDuino single-board-computer. This is the full size pcDuino board and includes the LVDS connector to connect an LCD touchscreen. Ideally suited for creating a wireless media centre.

- Built in Wi-Fi capability
- Supported digital audio via I2C.

NEW

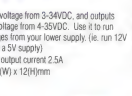
$19.95

## Arduino® Compatible Joystick Controller Module XC-4462

Similar to a PlayStation™ Controller, this shield has an analog joystick with a push down function button plus another four momentary push buttons. Add Bluetooth® module for a wireless controller.

- X,Y axis with push down button
- Voltage selectable 3.3V and 5VDC
- 87(L) x 54(W) x 18(H)mm

NEW

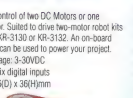


$9.95

## Arduino® Compatible 5V Stepper Motor
XC-4458

A small, versatile motor and driver set that can be used with any Arduino® or compatible boards via jumper leads. Four-phase LED indicates the status of the stepper motor.

- 35(L) x 32(W) x 10(H)mm



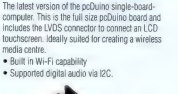
$9.95

NEW

## Arduino® Compatible 3W 200 Lumen LED Module
XC-4468

A high brightness LED in an easy to use modular package. Includes a PWM input for brightness control.

- Operating Voltage: 5VDC
- Colour Temperature: 6000K
- 30(L) x 23(W) x 6(H)mm



$29.95

## Voltage Converter Module
**FOR XC4350/52 PCDUINO** XC-4362

While most Arduino® shields run at 5V, the pcDuino runs at 3.3V. This shield safely marries 5V Arduino® shields with the 3.3V pcDuino and will stop damagecaused by connecting a 5V shield to the pcDuino.

- 70(L) x 50(W) x 4(D)mm

## GREAT SAVINGS ON THESE ARDUINO® PRODUCTS

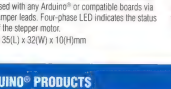
NOW $29.95
SAVE $14

## Large Dot Matrix Display Panel for Arduino®
XC-4250 **WAS $43.95**

This large, bright 512 LED matrix panel has on-board controller circuitry designed to make it easy to use straight from your Arduino® board.

- 32 x 16 high brightness blue LEDs on a 10mm pitch
- Viewable over 12 metres away

*Limited Stock. Available in-store only.*



NOW $49.95
SAVE $20

## EtherTen Board
XC-4216 **WAS $69.95**

Combining an Arduino® and an Ethernet shield onto one single board – includes onboard Ethernet, a USB-serial converter, and even Power-over-Ethernet support. Also features a microSD card slot for storing gigabytes of web server content or data.

*Limited Stock. Available in-store only.*

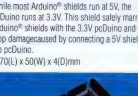
NOW $49.95
SAVE $20

## USBDroid – Interface with your Smartphone
XC-4222 **WAS $69.95**

Like an Arduino Eleven but with microSD slot & USB port. Enables you to build your own Android (insert registered tm logo) peripherals to connect your phone to whatever you like. Includes built-in charger for Android device.

- Compatible with the Android Open Accessory Development Kit
- 66 x 53mm

*Limited Stock.*



NOW $89
SAVE $30

## EtherMega, Mega Sized Arduino® 2560
XC-4256 **WAS $119**

The ultimate network-connected Arduino®-compatible board which features ATmega2560 MCU, onboard Ethernet, a USB-serial converter, a microSD card slot and an onboard switchmode voltage regulator so it can run up to 28VDC without overheating.

- 105(W) x 54(H) x 19(D)mm

*Limited Stock. Available in-store only.*

# PERIPHERALS ON SPECIAL
# NEW LOW PRICES UP TO 30% OFF
## STOCK IS LIMITED. ACT NOW TO AVOID DISAPPOINTMENT.

NOW $24.95
SAVE $10

### PCI-E USB 3.0 Interface Card
XC-4143 **WAS $34.95**

Slot this PCI-Express card into your motherboard for 2 x USB 3.0 ports and reach speeds of up to 4.8Gbps, ten times faster than USB 2.0. A cost effective upgrade for your desktop PC that will give compatibility for the next-generation of USB products.

*Limited Stock. Available in-store only.*

NOW $24.95
SAVE 29%

### High Definition 720p Webcam
QC-3203 **WAS $34.95**

Features a five-layer lens, high-resolution CMOS colour sensor ideal for video conferencing or webcam chat.

- HD 720p Video Recording (Max Resolution 1280 * 720).
- Built-in high sensitive stereo microphone
- Multi-utility camera base

NOW $14.95
SAVE $5

### Reversible USB 2.0 4 Port HUB
XC-4304 **WAS $19.95**

No more second guessing which way to insert your USB cable. You can insert your cable either way. Connect up to four devices.

- USB 2.0 compliant

**MUST HAVE TOOL KITS**

### 30pc Electronic Tool Kit
TD-2107 **WAS $29.95**

An electronic tool kit with all the essentials - cutters, pliers, screwdrivers etc. Ideal for servicing the computer.

NOW $24.95
SAVE 15%

NOW $39.95
SAVE $5

### USB 2.0 External 3.5" HDD Case
XC-4669 **WAS $44.95**

Accommodates a 3.5" SATA drive up to 3TB in storage capacity. Lightweight aluminium case for increased portability.

- USB 2.0 transfer rate up to 480Mbps.
- 183(D) x 117(W) x 31(H)mm

*Monitor not included.*

NOW $59.95
SAVE 25%

### Single LCD Monitor Desk Stand
CW-2839 **WAS $79.95**

Features a big sturdy base designed to keep your desk clutter free. Black powder coated scratch resistant finish, there is also the option of bolting it to a desk (will require drilling) if you require a more permanent installation.

- 490(H)mm pole, 270(L)mm arm
- Standard VESA mounting
- Recommended monitor size: Up to 22"

### 19pc Repair Kit for iPhone
TD-2113 **WAS $29.95**

All the tools you need to take apart your iPhone for DIY repair jobs.

*Limited stock.*

$19.95
SAVE 30%

**SIGN-UP IN-STORE OR ONLINE TODAY BY VISITING:**
**www.jaycar.com.au/nerdperks**

**TERMS AND CONDITIONS: REWARDS / NERD PERKS CARD HOLDERS FREE GIFT, % SAVING DEALS, DOUBLE POINTS & MEMBERS OFFERS** Require **ACTIVE** Jaycar Rewards / Nerd Perks Card membership at time of purchase. Refer to website for Rewards/ Nerd Perks Card T&Cs. **ON PAGE 2** get $15 off YH-6000 and $10 off YH-6004. **ON PAGE 5:** NP members get $5 off ST-2607 and $10 off XC-5175. **ON PAGE 4** get AR-1418 free with a purchase of CW-2831 or CW-2833. Get WW-7016 free with purchase of AC-1639, AC-1917 or XC-4873. Get $10 off YT-6000 **AND ON PAGE 7: 9 SAVINGS OFF ALL PRODUCTS ON SPECIAL FOR THIS FLYER MAY BE LIMITED IN STOCK.** Promotions may start and/or finish mid-week. **DOUBLE POINTS ACCRUED DURING THE PROMOTION PERIOD** will be allocated to the Nerd Perks card after the end of the promotion.

### Australian Capital Territory

| | |
|---|---|
| Belconnen | Ph (02) 6253 5700 |
| Fyshwick | Ph (02) 6239 1801 |
| Tuggeranong **NEW** | Ph (02) 6293 2270 |

### New South Wales

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|---|---|
| Albury | Ph (02) 6021 6798 |
| Alexandria | Ph (02) 9699 4699 |
| Bankstown | Ph (02) 9709 2822 |
| Blacktown | Ph (02) 8672 8400 |
| Bondi Junction | Ph (02) 9369 3899 |
| Brookvale | Ph (02) 9905 4130 |
| Campbelltown | Ph (02) 4625 0775 |
| Castle Hill | Ph (02) 9634 4470 |
| Coffs Harbour | Ph (02) 6651 5238 |
| Croydon | Ph (02) 9799 0402 |
| Dubbo | Ph (02) 6881 8778 |
| Erina | Ph (02) 4365 3433 |
| Gore Hill | Ph (02) 9439 4799 |
| Hornsby | Ph (02) 9476 6221 |
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| Smithfield | Ph (02) 9604 7411 |
| Sydney City | Ph (02) 9267 1614 |
| Tamworth | Ph (02) 6531 7033 |
| Tuggerah | Ph (02) 4353 5016 |
| Tweed Heads | Ph (07) 5524 6566 |
| Wagga Wagga | Ph (02) 6931 9333 |
| Warriewood | Ph (02) 9979 5722 |
| Warwick Farm | Ph (02) 8821 3100 |
| Wollongong | Ph (02) 4225 0969 |

### Queensland

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| Aspley | Ph (07) 3863 0099 |
| Browns Plains | Ph (07) 3800 0877 |
| Caboolture | Ph (07) 5432 3152 |
| Cairns | Ph (07) 4041 6747 |
| Cotswolds | Ph (07) 5491 1000 |
| Capalaba | Ph (07) 3245 2014 |
| Ipswich | Ph (07) 3282 5800 |
| Labrador | Ph (07) 5537 4295 |
| Mackay | Ph (07) 4953 0611 |
| Maroochydore | Ph (07) 5479 3511 |
| Memerald Beach | Ph (07) 5526 6722 |
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# PRODUCT SHOWCASE

## High-Resolution USB Oscilloscope, Spectrum Analyser and Signal Generator

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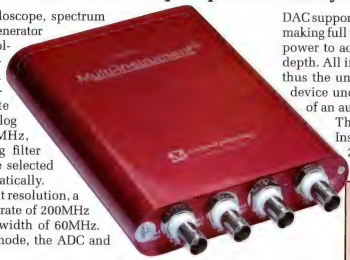

Its DAC has a 12-bit resolution, a maximum sampling rate of 200MHz and an analog bandwidth of 60MHz. Besides its normal mode, the ADC and DAC support streaming mode at up to 10M bytes/s, making full use of the PC resources and computing power to achieve a virtually unlimited memory depth. All instruments work simultaneously and thus the unit is very handy for characterising a device under test – eg, the frequency response of an audio amplifier.

The accompanying software, Multi-Instrument, can be downloaded for a 21-day fully functional free trial with a PC sound card.

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# SERVICEMAN'S LOG

## Ultimate servicing & my run of bad luck

**How can so much bad luck happen to one man? First, yours truly had to be carted off to hospital for some repairs of his own and then one thing after another went wrong after I got out. First my car played up, then my fridge, then my toaster oven. And then, to add insult to injury, my desktop computer refused to boot.**

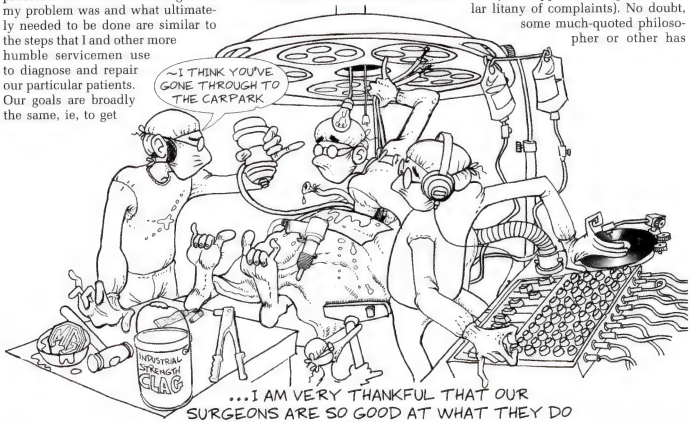
Recently, I had first-hand experience with a person whose occupation could probably be described as the "ultimate serviceman". I was the device being repaired and the serviceman was a skilled surgeon, supported by an equally capable team of professionals.

A surgeon spends years developing the methods and skills that allow him or her to repair us when things go wrong. It was particularly interesting for me because the troubleshooting processes used in determining what my problem was and what ultimately needed to be done are similar to the steps that I and other more humble servicemen use to diagnose and repair our particular patients. Our goals are broadly the same, ie, to get whatever we are fixing up and running again, the main difference being that the outcome of our efforts are not (usually) a matter of life or death.

I am very thankful that our surgeons are so good at what they do. Due to their efforts, I was able to get back to doing what I love to do and that brings me to my first story.

### Strike 1

I'm sure many of you have experienced the situation where several things go wrong all at the same time. I often get customers coming in claiming that not only has their computer just crashed but their car broke down yesterday and their lawn mower has also just stopped working (or a similar litany of complaints). No doubt, some much-quoted philosopher or other has




### Items Covered This Month

- Dave's run of bad luck
- Viewsonic monitor repair
- VAST satellite TV receiver
- Yamaha A-1020 amplifier repair
- The re-tyred mouse
- Another tale of two Topfields
- Dishlex dishwasher repair

*Dave Thompson runs PC Anytime in Christchurch, NZ.
Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

come up with a high-falutin' term for this phenomenon ("synchrodipity" or "serenicity" perhaps?) but I'll just call it a run of bad luck.

We experienced just such a run of bad luck ourselves recently and it gave us pause to wonder what we could have done to invoke the wrath of the Gods (or Murphy). It all started when I was driving my beloved but increasingly exasperating and wallet-emptying MG-F. All of a sudden, there was a weird sound and the righthand side of the car sank to the suspension stops.

As a result, the tyres began rubbing on the underside of the wheel-arches and since even the best-repaired roads around Christchurch these days resemble back-country 4-wheel drive trails (don't get me started), at least some suspension is necessary to avoid bruised kidneys and/or spinal compression injuries. And that's before we even get to upsetting my still-healing surgery wounds.

MG Rover, in their infinite wisdom, decided that the MG-F would use what would turn out to be the last implementation of their (in)famous BMC hydrolastic suspension system. This same system was used in early Minis and other British cars of the era.

In simple terms, this once-revolutionary system makes use of spheres filled with pressurised fluid at each corner of the car instead of springs to filter out bumps. Each side's front and rear spheres are connected together via high-pressure hydraulic lines, the idea being that a bump in the road will compress the front sphere and thus send more pressure to the rear, thereby readying it for its turn with the bump.

In practice, this system works extremely well and provides an excellent ride and brisk handling – ideal for a sports roadster. But one of my spheres had popped its cork and, as a result, driving the "F" was all but impossible. Fortunately, I wasn't allowed to drive for a couple of weeks post-surgery anyway, so that made my enforced grounding a bit more tolerable.

I won't bore you with details of this completely non-electrical car fix. Instead, I mention it only to illustrate the first of an apparent series of hardware failures that made up my particular bad-luck cluster.

## Strike 2

The second bit of bad luck to befall us recently occurred one evening when we opened the freezer door to retrieve the ice-cream, only to find that the ice had escaped from the tub, leaving only the cream behind. In that case, I used my finely-tuned trouble-shooting skills and experience with refrigeration engineering to determine that the freezer door seal had failed.

Much to my wife's relief, that meant that we wouldn't end up with a fridge-freezer lying in the middle of our living-room floor for the several weeks while I tried to learn a new trade via the Internet – all that before finally giving in and getting someone who really knows what they are doing to come and fix it.

Fortunately, new seals are readily available online and easily fitted, so a potential disaster was averted.

## Strike 3

The next first-world misfortune to befall us happened the other day when I fired up our trusty Australian-made toaster-oven to heat up some lunch while I prepared a drink (non-alcoholic, of course, given the time of day). For those who aren't familiar with these appliances, they are just a miniature oven that sits on the bench-top and are ideal for burning croissants and making grilled-cheese sandwiches.

In fact, the makers claim that you can prepare roasts and similar spectacular feasts but given the size of the appliance, I doubt that such a meal would feed more than one hungry person.

Anyway, I came back to the oven after the usual five minutes to check that my lunch wasn't burning and noticed that I could clearly see inside the oven through the glass door. My first thought was that the oven must have an interior light that I'd never noticed before and somehow it had come on. However, that thought only lasted a microsecond because at the exact moment I noticed the light, my nose registered an electrical burning smell and I could see my lunch was looking a touch more cooked than it should be.

Realising something was very amiss, I quickly twisted the rotary switch to "Off" and flung open the door. After removing my now "Cajun-style" meal, I could see what the problem was; the top-rear element had peeled open like a banana skin, leaving the insides hanging out all crooked and broken.

Once it had cooled down, I unplugged the mains cable from the wall and carried the oven outside to our BBQ table/outdoor workbench for a better look. I then found that the front element had also peeled open and it was clear that both top elements would need to be replaced if this oven was to live again.

The disassembly basically involved removing the Phillips-head PK-type screws holding the wrap-around stainless steel body to the framework inside the oven. However, when I got to one of the body screws that was deeply recessed into the front bezel, I found that the screwdriver wouldn't "bite". No matter what I did, I couldn't seem to position it in order to get a grip on the screw.

Eventually, I flipped the oven over so that I could see into the recess and could see right away that they had used a security screw in that position. A quick check on its opposite number revealed that a security screw had been used there as well.

Why they even bother with this sort of thing amazes me. If someone is keen enough to want to open this device up, then a stupid little screw or two isn't going to stop them. They will find a way around the problem one way or another and screwdriver bit sets that

**The photo at right shows the failed elements in the toaster-oven while above is the modified screwdriver that was used to remove the two security screws.**

will fit just about any type of screw are readily available.

In the case of our toaster-oven, the security screws used a slotted head with a centre "pip". Fortunately, I had encountered some of these screws in a device I serviced many years ago and at the time had modified a small screwdriver using a Dremel-type rotary tool fitted with a cutting disc. This had been used to create a small notch in the end of the driver, as shown in an accompanying photo.

Since I never throw tools away, it wasn't long before I found it. It fitted neatly either side of the bridge in the screw head and so both screws were easily removed (note to manufacturers: don't bother using these screws; those of us who really want to will bypass them anyway and they're just annoying).

With the shell finally removed and the top panel out of the way, the full glory of the element blow-out could be seen. The rest of the oven, although a bit grubby (as all ovens become after a while), was in reasonable condition and I figured that if I replaced all four elements, we'd soon be burning lunch again.

But first, I had to track down the necessary spares and so I hit the Internet. My first visit was to the manufacturer's website but as expected, it was as useless as mammalian protuberances on a male bovine. I then looked at the websites for some local appliance dealers and service outlets but their sites were hopeless as well.

Why they don't get proper websites made up rather than get their brother-in-law (or some other relative), who obviously has the creativity and design sense of a chimpanzee, to do it for them is beyond me. These guys would never consider having crude, hand-painted signs on their buildings and having the equivalent for a website, where most people find them these days, isn't a good look. Note to small businesses: get a proper website – it will attract customers rather than drive them to your competitors.

With no elements on offer in the usual places, I fired off emails to various spare parts outlets and manufacturers. All replied that those elements were no longer available and that I should go out and buy one of their ovens. However, I refused to believe that no-one made those elements any more. After some thought, I decided to take a quick look inside some brand-new benchtop ovens down at our local mall and that confirmed that the elements used in many differently-branded units appeared to be the same.

Of course, physical similarities don't necessarily guarantee an electrical match but they must be reasonably close given the specifications of these ovens. If anyone has any suggestions, please get in touch; unless four new elements cost more than a replacement oven, I'm keen to repair this one. It would be an almost criminal waste to consign it to landfill if it's at all possible that I can eventually track down elements for it.

## Strike 4

To top all this bad luck off, I recently fired up my main desktop computer only to see it hang during the "Loading Windows" screen. "Great, just what I need", I thought.

I initially suspected the hard drive, a 256GB SSD, but after unplugging all my drives and USB devices, the machine began hanging at different points during the POST (Power On Self Test). The on-board POST code at first indicated memory corruption but replacing the RAM gave the same result. It then indicated an ATA controller failure, then another code not listed in the book.

After a lot more serviceman's adjectives, I concluded that I'd likely have to spring for a replacement motherboard. However, as a last resort, I decided to try resetting and then re-flashing the BIOS. No updated BIOS version was available so I simply flashed the same revision and lo and behold, that fixed the problem.

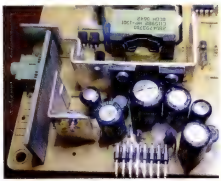
So the machine was rescued from the brink by good luck. Hopefully, that ends our current string of disasters (touch wood).

## Viewsonic monitor repair

My next tale of woe isn't technically part of our run of bad luck, although it is vaguely relevant.

Just before I moved out of my luxuriously large workshop in town to my 10m$^2$ cabin-workshop, a client gave me a high-end Viewsonic monitor which wasn't working properly. I plugged it in at the time and it would light up for a half a second before falling back into standby, a cycle that would then continue until it was switched off. When I subsequently moved workshops, I brought it with me, loathe to chuck it out as it was a very good monitor – or at least it would be if I could fix it.

As can be imagined, I've been tripping over it ever since. The other day, I banged my knee on it one too many times and with a curse hefted it onto the workbench to determine once and for all if it was going to stay or go into the skip. The usual screws and clips were undone, the stand unscrewed



**Above: the four bulging electrolytic capacitors in the Viewsonic monitor were easy to spot**

and plastic halves cracked and I soon had the circuit boards exposed. Sure enough, four of the electrolytic capacitors in the set were bulging and obviously causing problems.

As an aside, I was "bitten" by a charged capacitor in a monitor I was working on many years ago and since then I've been very careful. In fact, I recently made a dedicated capacitor discharging tool, mainly because I am working on a few valve amplifiers these days and the big filter capacitors in these can really bite if they are not properly discharged.

Before making this "discharger", I checked out some YouTube videos on discharging capacitors and was appalled at how many so-called servicemen recommend using a screwdriver to do the job. This is pure stupidity; by all means follow their advice if you want to ruin the tool and shorten the capacitor's life. Just be sure to wear safety gear to prevent bits of the capacitor's terminals or the end of the screwdriver from hitting you in the eye as they disintegrate due to the high current.

Personally, I prefer to use more sensible methods and in the past I've used a resistor connected in series with a couple of heavy-duty wire leads. Just recently though, I made a more permanent tool from a wooden file handle, a spare piece of sharpened steel shaft, a length of hook-up wire, a crocodile clip and a 100Ω 10W resistor. This allows me to discharge even the "gruntiest" capacitors without the tool-destroying, arc-welding splat that usually accompanies the screwdriver method.

Now back to that Viewsonic monitor which had been sitting around and taking up space for well over a year. Before getting anywhere near the circuit board, I used my new discharging tool to bridge all the visible electrolytic capacitors. The largest, a 1000µF unit, gave a healthy spark when shorted, indicating that it probably would have given me a sizable bite if I'd managed to get myself across it.

This is a warning to never expect a capacitor to be benign just because a device has been sitting unused for ages. Even though it was bulging and probably way off its specified value, this one still had enough stored energy to have given me a wallop.

Once all the faulty electros had been replaced, the monitor fired up and worked perfectly. It's now used

I WAS LOATHE TO CHUCK IT OUT AS IT WAS A VERY GOOD MONITOR

as a second screen for my workshop computer. In the meantime, I'm keeping my fingers crossed that this run of good luck continues!

## VAST satellite TV receiver

Sometimes, the simplest of faults can disable a piece of electronic equipment. L. W. of Logan, Qld recently saved an Altech DSD4121 VAST satellite TV receiver from going into landfill and can now enjoy his local TV channels when he does the grey nomad bit. Here's how he got it going again . . .

A fellow grey nomad recently purchased a new VAST satellite receiver when his old unit died. He was about to bin the old unit but then decided to ask me if I wanted it. If I could fix it, I could keep it and so it was that the receiver ended up on my workbench.

For those unfamiliar with VAST (Viewer Access Satellite Television), it's basically a digital satellite TV system for people living in regional and remote areas of Australia, who are unable to receive conventional broadcasts. Travellers (read grey nomads) are also able to utilise VAST via a restricted arrangement.

VAST is a free-to-air service and was launched on June 30, 2010. Up to 15 free-to-air channels are available and this is accessed via a VAST-certified decoder and satellite dish. The signal is received from the Optus C1 satellite (see **https://www.myvast.com.au/** for further information).

The unit in question was an Altech DSD4121 high-definition digital satellite receiver/decoder. In fact, Altech UEC was the first provider of VAST-certified digital set-top boxes and was also the first set-top provider in 1998 for the Aurora service. So there are a fair number of these units in operation, with most problems apparently occurring in the power supply.

After reading a number of posts on the internet (and noting that replacement power supplies ranged in price from $69 to $89), I was fairly certain that the problem with my unit would also lie in the power supply section. As a result, I removed the top cover and took a good look inside. This failed to turn up any obvious leads so I plugged the receiver into the mains via an isolation transformer (the power supply was a typical switchmode design and so part of it would operate at mains potential). I also noticed that the outputs on the PCB were labelled 12V, 5V & 3.3V.

Switching the receiver on produced absolutely nothing so I checked each output rail in turn. All three outputs gave a reading of 0V, so the power supply board was definitely unwell.

At that point, I was tempted to just send away for a replacement board, as these were readily available in both 230V and 12V versions. In fact, a 12V supply would be more suitable for my purposes, should I decide to press the receiver into service during our next caravanning adventure.

Unfortunately though, I didn't know if it was just the power supply that was faulty or whether there were further problems with the receiver. In view of this, I eventually decided to have a go at repairing the power supply myself.

The main IC in the supply was an LD7550 Green-Mode PWM Controller. I downloaded a data sheet for this device from the internet and this gave me some idea as to how the supply was designed. As with most data sheets, it had a "Typical Application" schematic and when I compared this to what I had in front of me, I found that there were lots of similarities.

Because all the output voltages were missing, it was obvious that the supply wasn't running at all, so I decided to direct my attention to the front-end. After disconnecting the power, I found that the full-wave bridge rectifier tested OK. I then discharged the main filter capacitor, as these usually sit at around 350V. The healthy spark generated during this process proved that this capacitor was in good condition.

My next step was to check the main switching device. This was a TSM 3N80 Mosfet and it tested OK. Some

# Yamaha A-1020 HiFi Amplifier Repair

Somehow, it seems that once you have repaired an item for a mate, it becomes your responsibility for evermore. M. H. of Woolloongabba, Qld recently took on a tricky fault in a friend's Yamaha A-1020 stereo amplifier. Here's what happened . . .

About 18 months ago, I fixed a fault in a friend's hifi system which, as it turned out, had nothing to do with the amplifier. But now the amplifier itself, a Yamaha A-1020, wasn't working, so "could I have a look at it again?"

Despite feeling a little reluctant to become further involved, I agreed to let him drop it around. The fault was simply described as "nothing comes out the speakers but the (front panel) lights come on".

On the bench, the unit was opened up and quickly inspected for bulging electrolytics, burnt components and fried cockroaches but finding nothing amiss, I plugged it in and turned it on. It soon became apparent that the speaker protection relay had not clicked in and a good thing too, because there was 63V on the left channel output when there should have been 0V. By contrast, the right channel appeared to be perfectly OK.

"This is going to be easy", I thought to myself. "it's either a shorted output transistor or perhaps a crook driver transistor".

Some quick in-circuit diode checks showed each of the bipolar output transistors to be as expected; ie, diode base-to-emitter, diode base-to-collector and high-impedance collector-to-emitter. The relevant electrolytic capacitors were then tested and each showed a good ESR figure, at which point I abandoned any notion that this was going to be an easy fix.

With the power applied again, I next checked the circuit voltages back from the faulty output stage. This revealed that each stage was being firmly driven towards the positive supply rail by the previous one. Basically, the emitter-follower output stage was driven high by a Darlington driver stage and this was driven high by a Class-A constant current source, in turn driven high by the input stage. However, there was no DC offset at the volume control, so the problem lay somewhere after that.

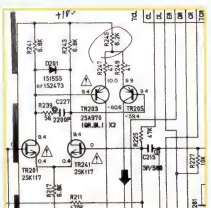


**Fig.1: the input circuitry of the power amplifier stages in the Yamaha A-1020 stereo amplifier.**

The input stage to the power amplifier is a fairly conventional N-channel JFET differential pair (see Fig.1). These in turn feed a PNP differential pair, one output of which goes to the Class-A voltage amplifier stage. Under normal circumstances, one could expect 0V on the gate of each JFET but with a steady 63V on the output, the inverting input of the differential pair was in fact at 14V.

This posed an immediate problem in that the gate-to-source/drain quick in-circuit tests of the other semiconductor devices didn't turn up any clues either, so I began to systematically work my way through the other components, starting at the main filter capacitor.

The typical application circuit in the data sheet proved to be a big help here. I was looking for the start-up components for the supply and the circuit led me to resistors R3 & R4. These are both 1MΩ resistors and are connected in series between Vcc and pin 2 of the LD7550 PWM controller.

R4 checked out OK at 997kΩ but R3 was open circuit. I then checked most of the other parts but all were OK so I replaced R3 and reinstalled the board back in the unit. I left the supply's output socket disconnected, then powered the unit up again via the isolation transformer. The power supply now produced healthy 12V, 5V & 3.3V rails so I switched off, connected the output socket to the main board and powered it up again.

And that was it – the unit went through its boot-up process and appeared to be working just fine. Connecting it to a TV resulted in a normal display screen and I was able to navigate through most of the menu items.

I now had a fully-functional receiver but of course, it couldn't produce any program content without a satellite dish and a suitable LNB (low-noise block). Once again, Google came to the rescue and within a few days I had a secondhand dish and LNB to play with.

With the dish set up and the LNB connected to the receiver via a coax cable, the next task was to align the dish to the satellite. I knew the dish had to point just off north at 356° and with an elevation of 61°. I had ordered a satellite finder on eBay but it was some weeks away and I really wanted some information on how to align the dish.

It was then that I remembered reading an article in SILICON CHIP some years ago on satellite TV reception. I searched through my old copies and found the 3-part series in the June, July & August 1991 issues. These described how to set up and align the dish and armed with this information, I was able to successfully receive a first-class picture and sound from the services available.

## Servicing Stories Wanted

**Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?**

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**Please be sure to include your full name and address details.**

diode junction, which is normally reverse biased for correct JFET operation, was thoroughly forward biased. That in turn was badly upsetting the operation of the differential pair and driving the following stages into cut-off, in turn pushing the output stage to the positive rail. This "full-on" output was then being fed back to the input and so was keeping the whole amplifier "hung up" on the rail.

As an aside, this "latch-up" phenomenon is well known when you overdrive the input of some early JFET op amps. But why was it happening here?

The AC feedback around the amplifier is routed via the tone controls directly to the gate of the inverting input JFET. However, the DC compensation is applied via a long time-constant RC network.

This arrangement ensures that fleeting excursions to the rails, such as at switch-on, do not have a chance to overdrive the input stage into latch up. The capacitor value was checked but was well within tolerance.

It wasn't practical to continue fault finding with the input stage latched up as it was, so I shorted the gate of the inverting input JFET to 0V by linking across the time-constant capacitor. This also allowed me to relax a little after previously realising that the fault condition had dumped 18V across an electrolytic capacitor rated at just 6V.

With the shorting link in place, the JFET differential pair were now producing roughly the correct voltages. However, the following PNP differential pair were still not feeding any current to the next stage, meaning that the final stage output was kept high. This didn't come as any surprise as the high-gain differential stages could easily magnify any inherent offset voltages and it was basically down to chance as to whether the output would go high or low with both inputs held at 0V.

Close scrutiny of the voltages around the PNP differential pair now revealed that the base-emitter junctions were forward biased and yet the signal path transistor still had no current flowing from emitter to collector. Feeling sure that I had found the culprit, I duly removed the transistor but much to my frustration, it tested perfectly OK.

So why was there a steady voltage across its emitter resistor and yet no current was reaching the next stage?

The focus now swung onto the emitter resistor itself, an 8.2kΩ pull-up to the 18V rail. Sure enough, a simple ohm-meter check showed that its value had risen to around 1MΩ. I removed it and installed a new 8.2kΩ resistor and the amplifier immediately came back to life. Job done.

That still left the mystery as to why a perfectly plain carbon-film resistor with minimal power dissipation had gone high. One possible explanation is that the resistor had been partly covered by an overflow of contact adhesive that had been applied to hold down a large electrolytic capacitor mounted next to it. Over time, the adhesive had become quite hard and this hardening had possibly stressed the resistor body enough to crack the internal carbon film track.

After more than a little tugging and pulling, the resistor was finally extracted from the hardened adhesive and it then measured completely open circuit. But even after all the rough handling, there were no visible signs of cracking on its body.

So the finer details of the failure mode remain something of a mystery. My friend, of course, was happy just to have his system working again and I've kept the circuit diagrams filed away, just in case I'm called on to look after "my" amplifier again.

On a recent trip to Inskip Point and Isla Gorge in South East Queensland, we tested the unit using a 12V-to-230V inverter to power it and were able to watch all our usual local channels just as if we were at home. And so, for the cost of a single resistor, another piece of useful electronic gear was saved from ending up on the local tip or in e-waste.

## The re-tyred mouse

What did G. I. of Castle Hill do when his wireless mouse got sick? Simple – he operated on it. Here's how he made it well again . . .

For some time now, I have been using a Microsoft Wireless Mouse 2000, together with a companion Microsoft wireless keyboard. It's a set-up that works really well – I hate having the mouse and keyboard tethered to a PC via connecting cords.

It all worked reliably for several years until recently when the mouse suddenly began playing up. This particular mouse has a flat rubber band (or tyre) around the scroll wheel and after many years of use and tens of thousands of scrolled pages, it had perished and gone all stretchy and gooey.

What's more, small rubber particles had begun breaking away and were finding their way into the scroll-wheel assembly inside the mouse. And that in turn was upsetting the photo-interrupter operation so that pages no longer scrolled smoothly (the scroll-wheel is basically just a rotating multi-vane assembly that interrupts the light between a LED and a photodiode).

Being the incredibly patient chap that I am, I persevered with it for longer than I should have until one day the rubber tyre finally broke. It was clearly time for a new mouse so I looked at several websites to see what I could find before venturing out to the stores. It was an exercise in frustration. Why in heaven's name do they make "meece" so small these days? OK, some people might want a compact mouse to lug around with a laptop but what if you have a desktop PC and want a proper mouse?

Anyway, after visiting several stores, I eventually settled on a Logitech M525 which appeared to be a decent size. When I got it home, all I had to do was plug the beastie's little receiver into one of my PC's USB ports and it worked perfectly.

But guess what – I preferred the feel of my old Microsoft 2000 mouse. The fact is, you get very used to using a particular mouse and a different model initially just doesn't feel right. It's like an old pair of shoes – a new pair is never as comfortable until they've been broken in.

And that set me thinking – perhaps I could take my Microsoft mouse apart and fix it? After all, I had nothing to lose. If it ended up in the bin, I still had my new mouse to fall back on.

It wasn't immediately apparent how it came apart, as there were no visible screws underneath or inside the battery compartment. However, I figured

# Another Tale Of Two Topfields

In the October 2015 issue, B. C. of Dungog, NSW described how he resurrected two faulty Topfield PVRs. This time around, he obtained two faulty Aurora Topfield TF3200IR DVB satellite boxes from the recyclers, hoping to getting at least one of them working. One was a write-off but his persistence paid off with the second unit . . .

For some years now, I have been receiving the ABC and SBS feeds, in the different time zones throughout Australia, on the Optus D1 satellite. However, my Star DVBS3800CA DVB satellite box's remote control interferes with some of the functions on my other electronic equipment.

Recently, during a clean-up in our area, two Aurora Topfield TF3200IR DVB satellite boxes turned up at the recyclers and I promptly purchased them for a song, the idea being to see if I could get at least one of them working again. Upon dismantling these units in my workshop, it was apparent that one had been for a swim and was beyond repair. However, the second one had suffered no such fate and it looked promising.

First, its switchmode power supply unit was removed and nearly all of its electrolytic capacitors were replaced since 11 of them had high ESR readings. The PSU was then refitted and the satellite box connected to a satellite dish and a TV monitor.

The Topfield TF3200IR's menus are very similar to their ubiquitous PVRs and STBs of that era. However, there are also some extra settings for the LNB frequency, the channel frequency and the symbol rate. All these settings are readily available on the www.lyngsat.com website for all Optus satellites and their feeds.

As it turned out, all the SBS feeds could be scanned in one-by-one on the Channel Search mode but unfortunately, none of the ABC feeds would scan in. As a result, everything was disconnected and the motherboard was removed from the case. All 27 electrolytic capacitors on the motherboard were then tested using an ESR meter and five gave high readings. These were all near the four voltage regulators on the motherboard, which was hardly a surprise.

After replacing the faulty capacitors and refitting the motherboard, I then found that I could scan in all the missing ABC feeds. That done, I exited the installation menu and then decided to let the Topfield satellite box soak test for a little while.

Unfortunately, there was still a problem. As the channel frequency increased, the picture had a tendency to pixelate and to become increasingly unstable. The signal strength was stable on the bargraph display but the quality bargraph display increasingly fluctuated as the frequency increased.

This Topfield satellite box is fitted with a Samsung tuner and that's where I expected the fault lay. As a result, I carefully removed both of its covers and found two 10µF 16V miniature electros inside which both tested high ESR. These were replaced and the covers then carefully refitted. Fortunately, there was just enough space to do this without desoldering and removing the tuner block from the motherboard!

And that was it – all the SBS and ABC feeds were now rock stable. But what about a suitable remote control? Fortunately, the remote controls used for the Topfield STB's will also work on their satellite boxes and I had some on hand. Best of all, they don't interfere with any of my other equipment and, as a bonus, the picture quality has also improved!

that they were probably hidden under the rubber glide strips located at either end, so I peeled the strips away. This revealed two screws at either end and undoing these allowed the upper section of the plastic case to be lifted free.

That left the main base section with its two PCB assemblies, the optical tracking pick-up and the scroll-wheel assembly. The latter is clipped into two split plastic support posts (one at either end) and I was able to remove this without breaking anything.

I then had to separate the two outer covers of the scroll-wheel assembly so that I could extract the scroll-wheel itself to fit a new tyre. The two covers had either been glued together or were a push-fit and I feared that forcing them apart would break something. In the end, there was nothing for it but to insert a flat-bladed screwdriver into a slot at one end and give it a twist.

To my surprise, it came apart without too much effort and I was then able to separate it at the other end and split the assembly. As it turned out, one section had a small plastic post at each end and these were originally a tight fit into matching holes in the other section. However, having separated them, the posts no longer fitted tightly, so I would have to find some other way of fastening them together when it came to reassembly.

Having split the cover assembly, I next removed the scroll-wheel by pulling it off its splined post in the centre of one of the covers. The scroll-wheel parts were then washed to remove the rubber particles and lint that had found their way inside the assembly. In addition, the main mouse assembly was cleaned using a soft brush before blowing it out with dry compressed air.

The next step was to conjure up a suitable rubber tyre. The scroll wheel is about 15mm across and I needed something that was not only a tight fit onto its rim but which wouldn't quickly perish. About the only thing I could think of off-hand was to try a rubber o-ring washer as used in taps.

I rummaged through my washer spares and soon found a suitable candidate. At 12mm across, it was a tight stretch to get it onto the scroll wheel but it went on after a bit of a struggle and it certainly looked the part.

The only problem was, it really wasn't wide enough so I thought I'd try using two o-ring washers side-by-side. Well, that was easier said than done. Getting the first washer on was fairly straightforward but much to my frustration, it would then slip off again as the second washer was rolled into place alongside it.

Eventually, after repeated attempts, I managed to get the two to stay on together and they fitted the width of the rim almost perfectly. The scroll wheel

was then carefully refitted to its fluted post on one of the outer covers and the second cover slipped into position. A hot soldering iron was then dabbed on the mating seam at either end to spot "weld" the two plastic covers together.

After that, it was just a matter of clipping the scroll-wheel assembly back into position, reattaching the top cover to the base and smoothing the shiny rubber glide strips back into position.

Did it work? – like a bought one! My Microsoft Mouse 2000 has many years of tracking and scrolling ahead of it yet.

## Dishlex dishwasher

Not all solenoids are equal as G. H. of Littlehampton, SA recently found out when repairing his dishwasher. Get it wrong and it's a case of water, water everywhere. Here's his story . . .

We own a Dishlex dishwasher which is now about 15 years old. About two years ago, it began tripping the circuit breaker in our meter box when it entered the final rinse cycle.

As it turned out, the fault was quite easy to track down. The water pump had partly come apart because of loose screws, causing it to leak into the tray underneath. A previous serviceman had left a wiring harness connector hanging down and this was being shorted out as the water level rose during the rinse cycle.

After making the necessary repairs, the unit then worked perfectly until about two months ago when it developed a different fault. This time, the dishwasher would go right through its cycle until it reached the final rinse cycle but would then stop. According to the instruction book, the fault code that appeared on the front-panel display indicated either a blocked water filter or a problem with the tap. That was rather strange, as the unit had filled and completed the previous cycles.

I dismantled the hoses and checked the filters but all was fine. I then decided to partly dismantle the machine so that I could get to the water inlet solenoid. My DMM quickly confirmed that 230VAC was being applied to the solenoid but it wasn't functioning so no water was getting through.

It was a weekend and there was nowhere I could immediately purchase another solenoid, so I decided to look around my junkbox. I eventually found one but it had a 12V DC coil. Everything else looked the same so I decided to swap over the coil (which was intact) from the faulty solenoid. It was a bit fiddly but in the end, it worked well on the test bench so I went ahead and installed it in the machine.

All went well initially and then the machine started to fill . . . and fill . . . and fill. I hit the stop button but it kept filling so I was forced to turn it off at the power point. By that stage, water was dripping from around the door and there was quite a lot of water on the floor. It took quite some time to clean it up. I then had to open the door and I could not believe how much water fell out. Again, it took me a long time to mop it up.

When everything was dry again, I got out the manual and checked the set-up instructions, as the solenoid seemed to work correctly. This dishwasher does not have anything to detect water level; instead, it's all done by time and this is set during the installation.

The fill time is set for one minute and 20 seconds but my machine was overflowing well before that so I decided that I needed to get the correct solenoid. Some research on the internet turned up the answer – the solenoid I had used was from a washing machine and has a flow rate of 16 litres per minute. By contrast, the correct solenoid for my dishwasher passes four litres per minute. No wonder I ended up with water everywhere!

The original solenoid wasn't available but I found a universal one from a local parts supplier. When I purchased it, I made sure it would only pass the required four litres per minute. All was well until I went to install it in the machine. It was exactly the same as the washing machine solenoid I had fitted but enclosed in the package was a plastic washer with small holes in it. And this washer had to be fitted to reduce the pressure.

The problem was, do I leave the original washer inside and add the extra one or should the extra washer be used to replace the original? No instructions were included, so I rang the supplier but no-one knew the answer. In the end, I took a chance and replaced the original washer with the extra one that had been supplied.

I then installed it and set the timing by pushing the appropriate buttons while it was filling, as detailed in the manual. The dishwasher has been working perfectly ever since. SC


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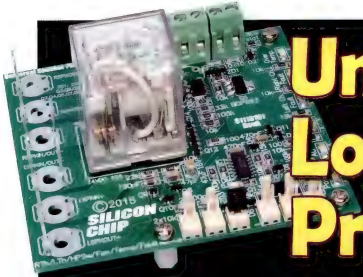


# Universal Loudspeaker Protector

By Nicholas Vinen

**This extensively revised Speaker Protection module protects your expensive loudspeakers from catastrophic faults in your amplifier. As well, it mutes switch-on and switch-off thumps, disconnects the speakers if you plug in your headphones and has heatsink temperature sensing in order to control a cooling fan in the amplifier. It also has on-board LEDs to indicate various fault conditions.**

ALL HIGH-POWER amplifiers should have an in-built Loudspeaker Protector. It will disconnect the speakers if the amplifier develops a serious fault which could result in a high DC voltage being applied to the speaker(s). Without the Loudspeaker Protector, the resulting high current would damage the speaker and in the worst case, set the speaker on fire!

You can imagine the scenario: you have the volume pumped up to enjoy your favourite music and suddenly one speaker emits a loud PFFTT and then nothing. Maybe the other channel stays just as loud. But before you realise you have a catastrophic fault, the damage is done; expensive damage.

Mind you, it could be a lot worse if you're having a party and you're not even in the room when the fault occurs – the speaker could catch fire! This can happen within seconds! In fact, in this article we have reproduced a series of photos which were taken for the article on our previous Loudspeaker Protector, featured in the October 2011 issue.

Some amplifiers have PTC thermistors in series with the outputs to prevent speaker damage and fire. These work because the high current which flows during a fault causes them to heat up and thus increase in resistance, limiting the power delivered. However, because they are non-linear devices, PTC thermistors can seriously affect distortion performance during normal operation of the amplifier.

Relays are much better in this regard but even they can have a secondary effect on distortion performance. Which is why we have been careful to verify that the relay used in this project does not have any significant effect.

Other roles played by the Loudspeaker Protector include muting any switch-on and switch-off thumps, disconnection of the speakers if the amplifier modules overheat (eg, due to being driven too hard), disconnecting the speakers when headphones are plugged in and running a small fan before the amplifier's heatsinks get too hot.

As noted above, we have included on-board indicator LEDs so you don't

## Features & Specifications

- Suits Ultra-LD Mk.4 110W/200W modules and other amplifiers with similar ratings
- Fast speaker disconnection with a sudden onset DC fault (typically <50ms)
- Compact PCB
- Operating voltage range: 15-55VAC or 22-50V DC (minimum 18VAC/24V DC if fan output used)
- Operating current: ~50mA (not including fan current)
- Switch-on and switch-off thump muting
- Temperature monitoring with overheat indicator and speaker disconnection
- Headphone speaker disconnection option using commonly available 3PST sockets
- Temperature sensing with thermostats or NTC thermistors
- Fan switch-on at a preset heatsink temperature
- Six on-board LEDs and two optional off-board status LEDs

**Without a Loudspeaker Protector, a serious fault in a high-power amplifier could cause enough current to flow through a speaker's voice coil to set the speaker on fire. These three photos, taken at 3-second intervals, illustrate just how quickly a fire can take hold once the cone ignites.**

have to guess what's going on. These show the presence of DC and AC (mains) power, relay operation, left and right channel fault status and over-temperature fault status. This makes testing the module and verifying its normal operation much easier.

The new design will run over a wide range of voltages without modification and has simplified supply wiring, partly because it has an on-board bridge rectifier; in many cases, one pair of wires from one of the transformer secondaries is all that's required to power it. All the extra features have been incorporated on a smaller PCB because we have employed a fair proportion of surface-mount devices, although these are relatively easy to install and solder.

## Circuit description

The Loudspeaker Protector module monitors seven inputs to determine when to connect or disconnect the speakers or turn on the fan or various LEDs. These seven inputs are: AC power, left channel DC offset, right channel DC offset, left and right channel temperature-sensing thermistors (if fitted), headphone jack socket switch (if fitted) and heatsink thermostat(s) (if fitted).

The full circuit is shown in Fig.1. The inputs mentioned above connect via CON1, CON3, CON4, CON5, CON9, CON13 & CON17. Let's go through these in sequence.

One of the amplifier's power supply transformer AC secondaries is connected to pin 3 of CON1. This voltage is applied to the emitter of NPN transistor Q3 and the base of NPN transistor Q4 via a 10kΩ resistor, with a 100kΩ pull-down to improve noise immunity.

If the voltage at pin 3 of CON1 is above about 0.7V, Q4's base-emitter junction is forward-biased and so its collector sinks current, turning on AC sense indicator LED2. Similarly, if the voltage at this pin is below about -0.7V, Q3's base-emitter junction is forward biased (it's operating as a common-base amplifier) and it pulls current from the base of PNP transistor Q12, switching the latter transistor on and thus the result is the same – LED2 turns on.

So LED2 is on while ever the absolute voltage at pin 3 of CON1 is more than 0.7V, which is true most of the time when mains power is applied to the transformer. As soon as the mains supply is switched off, the voltage at pin 3 drops to zero and LED2 turns off within milliseconds.

When Q4 or Q12 are on, they not only power LED2 but they also sink current via D1 and the series 100Ω resistor. This discharges the connected 470nF capacitor and thus NPN transistor Q9 is off. It in turn allows the 47μF capacitor connected to its collector via a 100Ω resistor to begin charging.

After a few seconds, this capacitor has charged to 14V and Q10's base-emitter junction becomes forward biased, because its emitter is limited to 13.5V, due to the voltage across zener diode ZD2 and regular diode D3. Q10 therefore switches on, sinking current from PNP transistor Q15's base which in turn powers the relay coil. With the relay on, LED3 also illuminates (as well as any external LED connected to CON8).

While the relay switch-on is delayed by several seconds while the 47μF capacitor charges, it switches off almost immediately when power is removed, since Q9 discharges it via a 100Ω resistor, a much lower value than the 100kΩ charging resistor. Thus, the speakers are disconnected before the collapsing power supply can cause the amplifier modules to deliver a transient and cause a thump, regardless of how long the main power supply reservoir capacitor charge lasts.

## Amplifier fault detection

Relay switch-off must be similarly fast should either power amplifier module (left or right channel) develop a fault which results in its output being pegged to a high positive or negative voltage – for example, a shorted output transistor. This is a bit tricky since normal output signals can contain significant excursions, eg, loud low-frequency bass.

The solution is to filter out the AC component of the signal from each channel with a simple RC low-pass filter comprising 22kΩ and 10kΩ re-

sistors and a 47µF capacitor for each channel.

The filtered, attenuated signal is fed to transistors Q5, Q6 & Q13 (left channel) or Q7, Q8 & Q14 (right channel) which are arranged in the same manner as Q3, Q4 & Q12 as described above and thus are also triggered by voltages exceeding about ±0.7V. If either fault detector channel is triggered, LED4 or LED5 illuminates and the 47µF time delay capacitor is quickly discharged via D2 and its 10Ω series resistor, disconnecting the speakers from the amplifier.

We tested this filter arrangement using LTSPICE simulations to check both that normal audio waveforms will not cause false triggering and that a serious amplifier fault will result in a quick switch-off. For example, a 15Hz sinewave delivering 200W into an 8-ohm speaker will not trigger this circuit, even with other higher-frequency, high-power signals mixed into it. This equates to a voltage swing higher than an Ultra-LD Mk.4 200W amplifier module is able to deliver.

However, if the amplifier offset goes from 0V to either +40V or -40V and stays there indefinitely, the fault detection circuit triggers in approximately 20ms. The relay itself takes a little time to switch off too but even taking this into account, the speakers should be disconnected in less than 50ms under these conditions.

By comparison, our October 2011 design takes nearly 50ms to even detect the fault, ie, more than twice as long, and the even earlier July 2007 design takes over a quarter of a second (250ms)!

Should the fault detection be triggered by, say, an extreme signal overload which is then removed, the speakers will be re-connected within a few seconds after amplifier operation returns to normal.

In addition, when the speakers are disconnected from the amplifier, the terminals are effectively shorted out, to blow out any arc which may occur between the relay contacts due to the high DC current being interrupted.

You might notice that there are empty pads on the PCB near the low-pass filter components. These were included for the connection of 100nF 100V capacitors across the 22kΩ resistors. Simulation shows that this speeds up fault detection by around 10%. However, they could potentially couple ground ripple voltage into the speaker outputs and thus affect distortion performance so we decided to omit them from the final design.

## Detecting other faults

As with the earlier designs, amplifier overheating can be detected by a normally-open thermostat bolted to each heatsink and wired across CON3. Multiple thermostats can be connected in parallel to monitor multiple heatsinks. When any one closes, the 47µF capacitor is discharged via D4 and thus the speakers are disconnected. When it cools down and opens, the speakers are re-connected after the normal delay.

However, this latest module also has provision to sense heatsink temperature using one or two 10kΩ NTC (negative temperature coefficient) thermistors. These are cheaper than thermostats and smaller, requiring only a single M3 screw for mounting. They are also more accurate (typically within 1°C or so) and since they can sense a range of temperatures, they can be used to control a cooling fan which comes on at a lower temperature, to cool the heatsink and possibly avoid ever disconnecting the speakers, even though you may have the volume "pumped up".

Also, since the thermistor temperature thresholds are set using a simple resistive divider, you can easily change them to suit your needs. With thermostats, you are limited in choice of temperature thresholds and hysteresis.

The thermistor(s) connect via CON4 and/or CON5. They form a voltage divider across the 24V supply, in combination with a 10kΩ resistor to ground. At 25°C, this results in ~12V at the junction, increasing as the thermistor heats up.

Comparators IC1a-IC1d monitor these voltages. These are part of an LM339 quad low-power comparator. IC1a compares the voltage from the thermistor at CON4 to a reference voltage formed by a 15kΩ/5.6kΩ/100kΩ divider across the 24V supply. This voltage will vary with the supply rail but so will the voltage from the thermistor, ie, it is a ratiometric comparison.

Pin 5 of IC1a is approximately 4.1V below the 24V rail. The specified thermistor has a beta of 3970. Using the calculator at www.daycounter.com/Calculators/Steinhart-Hart-Thermistor-Calculator.phtml, we determine its resistance is 2070Ω at 65°C. We will therefore have a voltage that's 4.12V below the 24V rail at pin 4 of IC1a. So at this temperature, the output of IC1a will go low, sinking current through PNP transistor Q16.

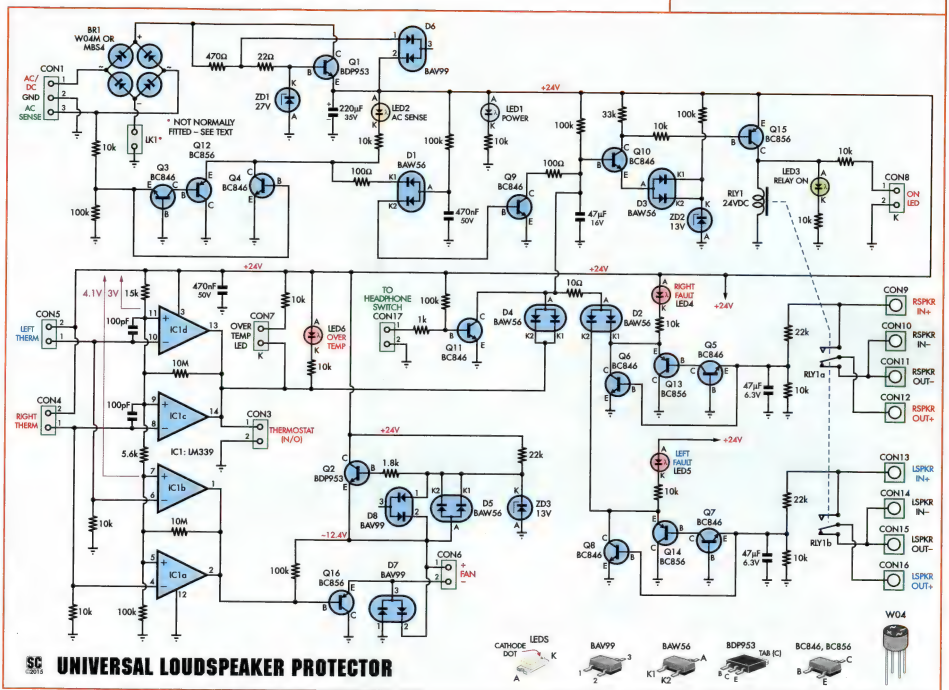
**Fig.1: the full circuit for the revised Speaker Protector. Transistors Q3, Q4 & Q12 monitor the presence of AC power while Q5/Q6/Q13 and Q7/Q8/Q14 monitor the left and right amplifier channel DC offsets in a similar manner. IC1 monitors the NTC thermistor resistance at CON4 and CON5 and either switches on a fan at CON6 or switches off the main speaker relay RLY1 if the temperature gets too high. Onboard rectifier BR1 and the 220µF filter capacitor provide a DC supply for the circuit while Q1 and ZD1 regulate the voltage to an average of around 24V DC. Similarly, Q2 and ZD3 provide a current-limited 12V supply for the optional cooling fan.**

Q16 operates as an emitter-follower, powering the optional 12V fan at CON6. Comparator IC1b works exactly the same way for the other thermistor and since the open-collector outputs are joined together, the fan will turn on when either heatsink exceeds 65°C.

If either reaches 75°C, the associated thermistor resistance drops to 1477Ω. Thus, pin 8 of IC1c or pin 10 of IC1d will be just 3V below the 24V rail. Both non-inverting inputs (pins 9 & 11) are 2.98V below this rail, so above 75°C, the output of IC1c or IC1d will go low. Over-temperature indicator LED6 will then light and the 47µF time delay capacitor will be discharged via D4, switching off RLY1.

A 10MΩ resistor from the common IC1c/IC1d output (pins 13 & 14) to their common non-inverting input pins (9 & 11) provides a little hysteresis, so that the relay does not switch on and off rapidly. Once the relay is off, the heatsink temperature must drop by several degrees before it will switch back on. Similarly, the 10MΩ hysteresis resistor for IC1a/IC1b ensures that once the fan has switched on, the heatsink temperature must drop by a degree or two before it will switch back off.

The two 100pF capacitors filter out any RF that may be picked up by the thermistor leads. If either or both thermistors are not connected, the associated pin will be pulled down to ground by the 10kΩ resistor and this




**UNIVERSAL LOUDSPEAKER PROTECTOR**

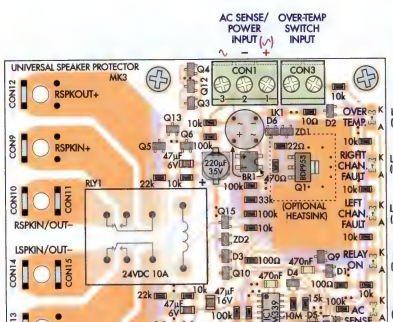



**Fig.2: use this layout diagram to build the speaker protector. Fit the SMDs first, followed by the remaining components in order of ascending height. BR1 and the 220µF electrolytic capacitor can be either SMD or through-hole parts. It's recommended to fit a heatsink where shown if the fan output is being used. Take care with LED orientation; if in doubt, use a DMM to check which end is the cathode. LK1 is normally not fitted (see text).**

## Attaching Non-Solder Spade Lug Connectors

Fig.3 (right) shows how double-ended non-solder spade lugs are mounted. Each lug is secured using an M4 x 10mm screw, a flat washer (which goes against the PCB pad), an M4 star lockwasher and an M4 nut.

The trick to installing them is to first do the nut up finger-tight, then rotate the spade lug assembly so that it is at a right-angle to the PCB. A screwdriver is then used to hold the M4 screw and the spade lug stationary while the nut is tightened from below using an M4 socket and ratchet.

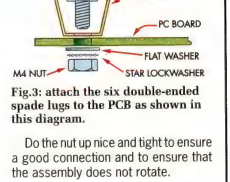



**Fig.3: attach the six double-ended spade lugs to the PCB as shown in this diagram.**

Do the nut up nice and tight to ensure a good connection and to ensure that the assembly does not rotate.

will disable temperature monitoring for that channel.

## Headphone switching

Generally we want to disconnect the speakers when a headphone jack is inserted. The signal for the headphones is taken from before the speaker protector relay so that output is not affected.

Most jack sockets have a switched ground terminal for the sleeve which opens when a jack is inserted. This is wired to pin 1 of CON17 so that when a plug is inserted, the base of NPN transistor Q11 is pulled high via a 100kΩ resistor. Thus Q11 turns on, discharging the 47µF capacitor and switching RLY1 off. When the plug is removed, it switches on again after the usual delay. If this feature is not needed, CON17 is shorted out (eg, with a jumper shunt) to disable Q11.

## Power supply

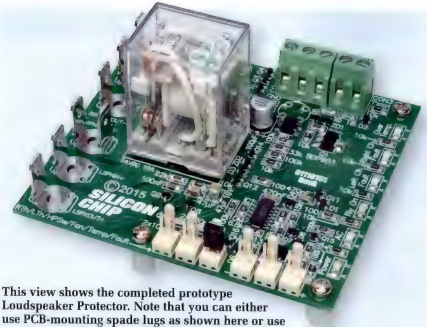
Our previous loudspeaker protector designs required changing a power resistor (or linking it out), depending on the supply voltage used, so that the relay's coil was supplied with the correct voltage. We've now eliminated that requirement by using a transistor and zener diode to provide a semi-regulated supply for the relay coil. The specified relay will operate just fine with a little ripple voltage across its coil, as long as it stays within the range of about 18-27V.

The easiest way to power this unit is from the transformer winding(s) which are used to power the amplifier modules. One end goes to pin 3 of CON1, for both AC sensing and connection to bridge rectifier BR1, while pin 2 of CON1 goes to ground/earth, as shown in Fig.5. This results in half-wave rectification, giving a pulsating DC voltage at the positive terminal of BR1.

This charges the 220µF capacitor via NPN transistor Q1. The 27V zener diode at its base is biased from the output of BR1 and prevents the 220µF capacitor charge from exceeding 27V, as ZD1 shunts Q1's base drive above this voltage. While the diodes in BR1 are forward-biased, the voltage in this capacitor is maintained via Q1. The rest of the time, this capacitor supplies the load current and recharges on the next mains cycle.

The voltage drop across Q1 results in heat dissipation of less than 1W during normal operation or around 2W with a fan attached and running (drawing around 100mA). The PCB acts as a heatsink to safely dissipate this heat. Q1 is rated for 5W dissipation as long as the PCB temperature is kept below 100°C.

With the copper plane provided, junction-to-ambient thermal resistance is about 40°C/W so, in theory at least, no heatsink is required. **In practice, Q1 gets very hot to the touch if the board is driving a fan so we strongly recommend you glue a small heatsink on top of Q1 if connecting a fan.** There are more details on this below.




**This view shows the completed prototype Loudspeaker Protector. Note that you can either use PCB-mounting spade lugs as shown here or use double-ended chassis-mounted types (see panel).**

Dual series diode D6, in combination with the 22Ω base resistor, limits Q1's base current to 0.6V ÷ 22Ω = 27mA which in combination with its beta of around 100 provides a peak collector current of around 3A. This is close to its continuous rating of 3A and well below its 10ms peak rating of 5A.

If the unit is run from a centre-tapped transformer secondary with an AC voltage less than 35V-0-35V, both ends of the winding should be connected to CON1 (pins 1 & 3), giving full-wave rectification and 100Hz recharge of the 220µF capacitor. Otherwise the ripple may be so great that RLY1 can't remain latched over the whole mains cycle.

With higher supply voltages this is not only unnecessary but will likely increase dissipation in Q1. The key point is that the voltage across the 220µF capacitor should not drop below about 18V as RLY1's "must operate" voltage is 16.8V.

## Powering a fan

Most small DC fans run from 12V so we've provided a 12V current-limited supply. This can be bypassed if a 24V type is used. Use a 24V fan if you can get a suitable type, since the fan will receive more power and less will be dissipated in the speaker protector power supply. Either way, the fan negative terminal is pulled to ground to turn the fan on or left floating to turn it off.

The ~12V rail is derived by NPN transistor Q2 from the 24V rail in a similar manner to the way that the 24V rail itself is derived by Q1. The 1.8kΩ base resistor, in combination with dual series diode D8 limits its base current to 0.6V ÷ 1.8kΩ = 0.33mA which, with a beta of 350, gives a maximum collector current of just over 100mA.

This protects Q1 and Q2 in case the fan terminals are shorted out. It also protects both transistors against excessive dissipation should the fan try to draw more than 100mA (as many 12V fans would). Basically, if that happens, the supply voltage will drop and it will simply run slower.

Diodes D5, and D7 absorb any inductive spikes which may be generated by the fan motor, especially when it is switched off, and prevent Q16's base-emitter or emitter-collector junctions from becoming reverse-biased.

If a fan is to be used, dissipation in Q1 will be lower if the module is driven from a centre-tapped low-voltage transformer winding of at least 18V-0-18V. With lower voltages, depending on the fan current draw, supply ripple may be too high for the unit to operate properly. In this case, you have to run the unit from the higher voltage windings on the transformer, as shown in Fig.5.

If driving a fan and running the unit off a much higher voltage transformer secondary, it's a good idea to fit a small heatsink to Q1, as explained earlier and described below.

If using a 24V fan, ZD3 should be omitted and the nearby 22kΩ resistor replaced with a 0Ω resistor (or a wire link).

## Changing thresholds

If using NTC thermistors, the temperature thresholds can be changed by varying the value of two resistors. As explained above, the fan will normally switch on at 65°C ($T_{FAN}$) and the speakers are disconnected at 75°C ($T_{OVERHEAT}$).

Let's say you want $T_{FAN}$ = 60°C and $T_{OVERHEAT}$ = 70°C instead. First, calculate the expected NTC thermistor resistance at these temperatures using the website listed previously: **www.daycounter.com/Calculators/Steinhart-Hart-Thermistor-Calculator.phtml**

Plug in beta = 3970, R1 = 10,000Ω, T1 = 25°C and T2 = 60°C to get $R_{FAN}$ = 2468.7Ω. For T2 = 70°C we get $R_{OVERHEAT}$ = 1744.4Ω.

Since the reference voltage divider string has a 100kΩ resistor at the bottom, compared to the 10kΩ divider resistor for the NTC thermistors, the total value of our two new resistors (to replace the 5.6kΩ & 15kΩ resistors) will need to be $R_{FAN}$ x 10, ie, 24,687 ohms ($R_{TOTAL}$).

We can now calculate the new value for the 15kΩ resistor as (100,000Ω + $R_{TOTAL}$) x $R_{OVERHEAT}$ ÷ ($R_{OVERHEAT}$ + 10,000Ω) = 18,519Ω. 18kΩ is close enough. The 5.6kΩ resistor is then replaced with a value of 24,687Ω – 18,000Ω = 6687Ω, which is close to 6.8kΩ. Substitute different thermistor resistance values into these formulae to calculate the required components for other temperatures.

## Construction

The Speaker Protector module is built on a double-sided PCB coded 01110151 and measuring 88 x 79mm. Most of the components are SMDs. The exceptions are the connectors, RLY1 and optionally, bridge rectifier BR1 and the 220µF electrolytic capacitor. Fig.2 shows the assembly details.

Start with the sole IC, comparator IC1. Locate its pin 1; this will normally be indicated by a dot, divot or failing that, a bevelled edge. Rotate the IC so that pin 1 is at upper left as shown. Tack-solder one pin, then check that all the other pins are properly centred over their pads. You can either solder them individually or you can add flux paste down both sides of the IC and then use a wave-soldering technique.

## Parts List: Loudspeaker Protector

1 double-sided PCB, code 01110151, 88 x 79mm
8 6.3mm PCB-mounting spade terminals, 5mm pitch (CON9-CON16) (Jaycar PT4914, Altronics H2094) OR
6 double-ended chassis-mounting spade terminals with M4 x 10mm machine screws, shakeproof washers, flat washers and nuts
1 3-way terminal block, 5.08mm pitch (CON1)
1 2-way terminal block, 5.08mm pitch (CON3)
6 2-way polarised headers, 2.54mm pitch (CON4-CON8, CON17)
1 24V DC coil, 10A DPDT cradle relay with integral LED (RLY1) (Altronics S-4313)
4 M3 tapped spacers
4 M3 x 6mm pan-head machine screws
1 shorting block
2 10kΩ lug mounting NTC thermistors (Altronics R4112) (optional)
1 12V or 24V DC fan (optional)
1 9V battery (for testing)
1 or 2 small finned heatsinks with adhesive pads (optional, see text)

Various lengths of hook-up wire and header plugs as required

**Semiconductors**

1 LM339 comparator (SOIC-14) (IC1)
2 BDP953 100V 3A high-gain NPN transistors (SOT-223) (Q1,Q2)
9 BC846 NPN transistors (SOT-23) (Q3-Q11)
5 BC856 PNP transistors (SOT-23) (Q12-Q16)
1 27V 0.25W zener diode (SOT-23) (ZD1)
2 13V 0.25W zener diodes (SOT-23) (ZD2,ZD3)
1 400V 0.5A SMD bridge rectifier, MBS4 type (BR1) OR
1 W04 1A bridge rectifier (BR1)
5 BAW56 dual common anode diodes (SOT-23) (D1-D5)
3 BAV99 dual series diodes (SOT-23) (D6-D8)
1 high-brightness blue LED, 3216/1206 size (LED1)
1 high-brightness yellow LED, 3216/1206 size (LED2)
1 high-brightness green LED, 3216/1206 size (LED3)
2 high-brightness red LEDs, 3216/1206 size (LED4,LED5)
1 high-brightness amber LED, 3216/1206 size (LED6)
1 or 2 chassis-mounting LEDs for status indication (optional, see text)

**Capacitors (3216/1206 unless stated)**

1 220µF 35V SMD or through-hole electrolytic, up to 8mm diameter (eg, Nichicon UCW1V221MNL1GS; Digi-Key 493-9430-1-ND)
2 47µF 6.3V X5R
1 47µF 16V X5R (3224/1210 or 3216/1206 size)
2 470nF 50V X7R
2 100pF 50V C0G

**Resistors (all 3216/1206, 0.25W 1%)**

| | |
|---|---|
| 2 10MΩ | 1 15kΩ |
| 7 100kΩ | 14 10kΩ |
| 1 33kΩ | 1 5.6kΩ |
| 3 22kΩ | 1 1.8kΩ |

1 1.8kΩ 0.25W through-hole (for testing)
1 1kΩ 0.25W through-hole (for testing)

| | |
|---|---|
| 1 1kΩ | 2 100Ω |
| 1 470Ω 0.5W | 1 22Ω |

2 10Ω (one optional for LK1)

Once all the pins have been soldered, check for bridges between them and use flux paste and solder wick to remove any bridges you find.

The next job is to mount the 27 SOT-23 package transistors and diodes. These are quite small but the pins are spaced fairly far apart. The orientation of each is obvious due to the fact that they have one pin on one side and two on the other but do be careful not to get the six different types of components mixed up and make sure they are not fitted upside-down, ie, their leads should be in contact with the PCB pads.

The basic technique is the same as for the IC – tack solder one pin, check the positioning, solder the other two pins and then refresh the initial solder joint with a little flux paste or added solder.

The two larger BDP953 transistors can be soldered in place now. These are in SOT-223 packages which do an excellent job of transferring heat to the PCB due to their large, thin tabs on which the silicon die is mounted.

The easiest technique (excluding hot-air or IR reflow) is to put a little flux paste on the large pad, then tack the part down at one of the smaller end pins. You can then solder the large tab; it will take a little while before the part and PCB heat up sufficiently to form a proper solder joint but the flux paste should help the solder flow under the tab. You then immediately solder the centre small pin (which is connected electrically to the tab) and finally the two outer pins.

### Fitting the LEDs

There are five different colour LEDs and the first step before soldering each one is to verify its polarity. Use a DMM set on diode test mode and carefully probe both ends of the LED package. When it lights up, the red probe is on the anode and the black probe on the cathode. The polarity is marked on the PCB and shown in Fig.2 so solder it to the appropriate pad with the correct orientation.

Often, the cathode is marked with a green dot – but not always so be careful!

Since LED1 is blue and has a forward voltage of more than 3V, depending on your DMM it might not light up either way around. In this case you'll either have to trust the cathode marking or use a 9V battery with a series current-limiting resistor and a couple of short lengths of wire to probe it.

Solder them using the usual method of tacking down one end, soldering the other and then refreshing the first. Try to solder them with the base flat on the PCB.

The resistors and ceramic capacitors can now be mounted using the same basic technique. The resistors will be printed with a 3-digit or 4-digit code indicating their value (eg, 10kΩ = 103 or 1002) while the capacitors will not have any markings and you will have to check the packaging. **Make sure you don't get the 47µF 16V capacitor mixed up with the two 47µF 6.3V capacitors; the former is likely to be bulkier.**

Similarly, the 470nF capacitors will be thinner than the 47µF capacitors and the 100pF thinner again.

Fit the electrolytic capacitor next,

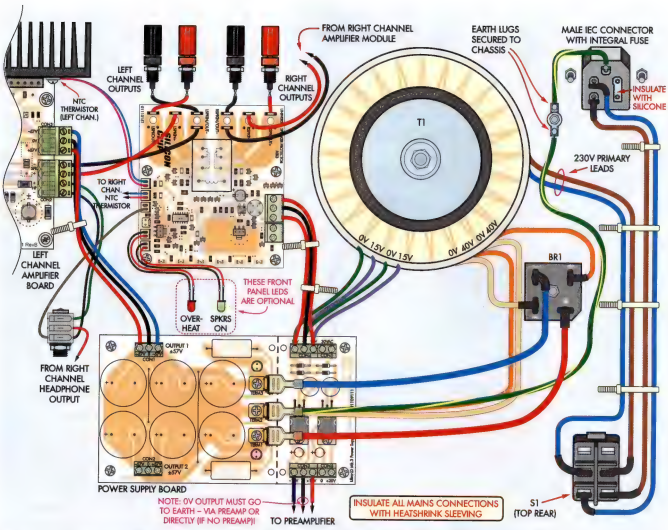



**Fig.4: here's how to connect the speaker protector module when the transformer has a low-voltage set of secondaries. In this case, they're being fed to a power supply board to provide regulated ±15V rails for a preamplifier. Note that in this case, the speaker protector will only work if the transformer centre tap is connected to Earth via the regulator board and preamp. Note also the single wire from the headphone socket to the module; this is done to avoid an Earth loop (the ground connection is provided by the power supply).**

orientated as shown in Fig.2. It will normally have a bevelled base indicating the positive end and a black stripe on the negative end of the can. Solder its two metal pins similarly to the ceramic capacitors. You can use a regular through-hole electrolytic if you prefer, as mounting holes are provided. In this case, the longer lead goes though the pad towards the bottom of the board (ie, positive).

Similarly, the bridge rectifier can be an SMD or W02/W04 through-hole type. The SMD type will have a notch at the right-hand end (between the two AC terminals) while the through-hole type has a "+" printed above one lead (longer than the others) which goes in the pad indicated on the PCB. There's no need to fit both bridges.

Solder the polarised pin headers in place next, orientated as shown, followed by the two terminal blocks, with their wire entry holes towards the top of the board. Note that they are not dovetailed, ie, they're fitted separately.

The spade lugs are now soldered in place in the positions shown in Fig.2. Two are required for the negative polarity speaker terminals but only one for the positive polarity terminals. Try to solder them in at right angles to the PCB but don't hold them while soldering as they get extremely hot!

Alternatively, you can attach chassis-mount spade lugs to the PCB using M4 x 10mm machine screws, nuts and washers, as shown in Fig.3. Use shakeproof and flat washers to ensure good electrical connections between the spade lugs and the PCB pads and to ensure that they don't come loose.

All that's left is the relay. Ensure this is pushed all the way down onto the PCB before soldering its pins. It will only go in one way.

## Changing component values

Remember that you may want to change a few of the components to suit your application. These include: the 15kΩ and 5.6kΩ resistors if you are changing the temperature thresholds and ZD3 and its associated 22kΩ resistor if using a 24V fan.

**Note that LK1 is normally NOT fitted.** Fit LK1 if and only if both the following are true: the transformer winding powering the module is not connected to earth or anything else (including any other taps on the same winding) and the total winding voltage connected to the unit is no more than

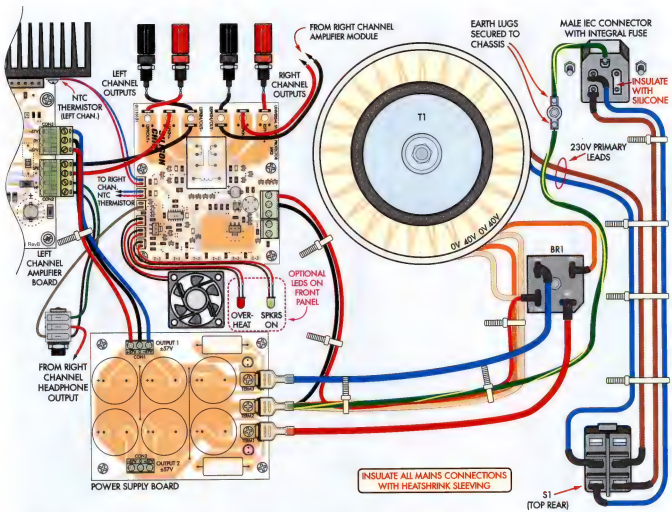



**Fig.5: here's how to wire up the speaker protector module so that it runs off the same transformer secondary as the power amplifier module(s). This will be necessary if the transformer only has the one set of secondaries (eg, in an amplifier with no preamp) or if you want the extra current to run a fan. Only one pair of supply wires is required unless the transformer secondary voltage is below 35V-0-35V. Note how the supply wiring is routed – this is to minimise any hum radiation due to the pulsating current draw of the unit.**

24V. You can use a 10Ω SMD resistor for LK1 if required. Basically, if unsure whether you need LK1, leave it out!

## Fitting a heatsink

While it certainly won't hurt to attach a small heatsink to Q1, as mentioned earlier, it isn't strictly necessary unless you are running a fan. Q2 typically dissipates less than 1.5W but it also has a smaller copper pad on the PCB and will get pretty hot when the fan is running, so you may want to put a small heatsink on it too.

Just about any small finned heatsink will work. We used a small anodised aluminium heatsink on our prototype. This is designed to be attached to the top of a 14-pin DIP IC (or similar). We got it from Rockby (Stock No. 26001) and attached it using a piece cut from an adhesive silicone insulating washer.

The Jaycar HH8580 pin grid array heatsink should also be suitable and comes with an adhesive pad pre-attached. Simply peel off the backing tape and press it down hard on top of Q1 and it should stay there. There's less room around Q2 so you'd have to offset it a bit but the same comment applies.

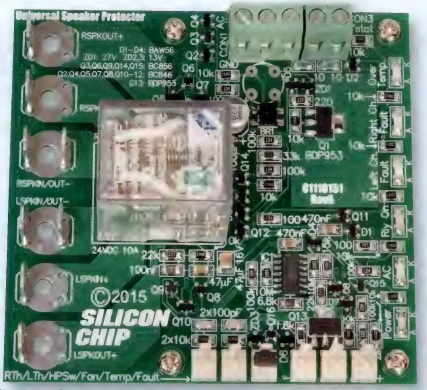
## Testing

Thanks to the on-board indicator LEDs, testing the module is pretty simple. First, place a shorting block on CON17. Then hook up a source of medium-voltage AC or DC power to pins 1 and 2 of CON1 (middle and right-hand terminals, looking at the board as shown in Fig.2). If using DC, ensure the negative terminal is connected to pin 2, otherwise the supply will be shorted out by BR1.

Ideally, use 18-25VAC or ~30V DC. A series resistor of say 100Ω 5W can be connected to protect the supply and PCB in case of a construction error.

Apply power and check that LED1 (Power) lights. None of the other LEDs should light yet. If possible, measure the supply current (eg, by measuring the voltage across the safety resistor). You should get a reading of around 10mA. If the LEDs do not light up as expected, or the current drain is excessive, switch off and check for soldering or component placement mistakes.

Assuming it's all OK, measure the voltage across the electrolytic capacitor by touching the DMM's probes to the pads on the top of the PCB. If the incoming supply voltage is high enough for the unit to attain regulation, you should get a reading close to 27V. Now temporarily connect a convenient resistor (eg, 1kΩ 0.25W) between




**Here's another view of the fully-assembled prototype PCB. Be sure to install all the SMDs before installing the larger through-hole parts (see text).**

pins 1 and 3 of CON1, eg, by touching it across the two screw heads.

You should see LED2 (AC presence, yellow) light up when it is connected and LED2 should switch off immediately upon removal. Hold it in place for a few seconds and RLY1 should click on. At the same time, LED3 (Relay On, green) should light up. Remove the resistor and the relay should immediately turn off, along with LED3.

Power down and move the supply lead from pin 1 of CON1 (righthand end) to pin 3 (lefthand end). Power back on and wait for the relay to switch on. Then connect a spare 9V battery between supply ground (ie, pin 2 of CON1) and the LSPKIN+ terminal. LED4 (Left Channel Fault, red) should immediately light up and the relay should click off, along with LED3. Reverse the polarity of the battery and check that the same thing happens.

Now perform the same tests but this time with the RSPKIN+ terminal. LED5 (Right Channel Fault, red) should light and the relay should again click off for both polarities.

If using a fan, connect it up now, then clip a 1.8kΩ resistor across one of the thermistor terminals. The fan should switch on but RLY1 should remain engaged and LED3 should not go out. Test the other thermistor terminal; it should behave the same way. Now do the same test on both terminals with a 1kΩ resistor. In both cases, RLY1 and LED3 should switch off and LED6 (Over Temperature, red) should light.

You can also check that shorting out the terminals of CON3 has the same effect, ie, RLY1 and LED3 switch off and LED6 lights.

## Installation

The unit mounts in the amplifier chassis on four tapped spacers. Mark out the holes using the PCB as a template and drill them to 3mm. The basic wiring arrangement is shown in Figs.4 & 5. Fig.4 shows the arrangement when the transformer has suitable low-voltage secondaries, while Fig.5 shows the wiring when powering the unit from the same transformer secondaries as the amplifier module(s).

**Note that high AC & DC voltages are present in the power supply – see the warnings on pages 39 & 44 of the October issue.**

Use heavy-duty figure-8 cable for the loudspeaker connections. It doesn't matter if you swap the left and right channels around if it simplifies the wiring but either way, ensure that the polarity (±) is correct. You can check by using a DMM to test for continuity between the LSPKIN– and RSPKIN– terminals and chassis earth (once the power amplifier supply wiring is complete).

## Temperature Sensors

Temperature sensors are variously called "thermostat switches", "thermal cutouts" and "thermal circuit breakers" and are available in a range of trip temperatures from 50-100°C. Both NO and NC (normally-closed) temperature sensors are available but the temperature sensor used with this unit must be a *normally open* (*NO*) type.

A thermal cutout rated at 70°C (eg, Jaycar ST3831) is suitable for the Ultra-LD Mk.4 amplifier (and for earlier versions). Alternatively, use the Altronics S5591 which is rated at 60°C.

Note the way we've shown the power supply wiring in Fig.5. This minimises the AC magnetic field around the wires. Also note that the AC supply connection must go to pin 3 of CON1 as shown. For a centre-tapped connection (as in Fig.4), use three lengths of hook-up wire twisted together and/or encapsulated in heatshrink tubing. The power supply current is normally 50-150mA so medium/light-duty wire is OK.

If using thermostat(s), wire these in parallel to CON3. Their polarity does not matter. If using NTC thermistors, connect these to CON4 & CON5 as shown in Figs.4 & 5. The thermistors are also non-polarised.

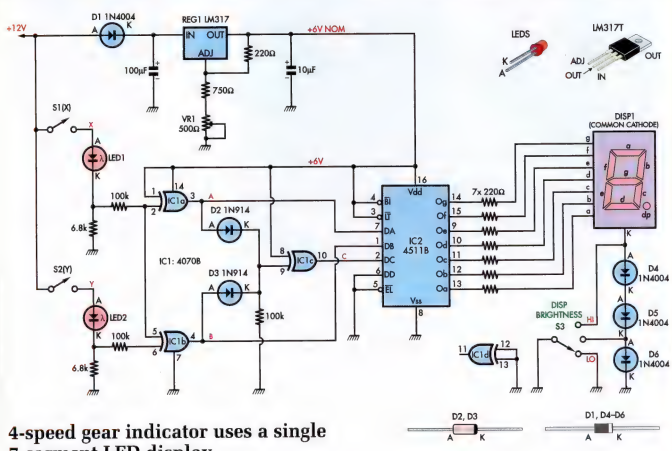
For speaker disconnection when headphones are inserted, run a single wire from the switched terminal on the jack socket to the relevant terminal of the headphone switch connector (CON17) on the PCB as shown. The ground connection is made through the power supply wiring. If not using this feature, place a shorting block across this header instead.

## Indicator LEDs

The two front-panel indicator LEDs are optional and you can fit none, one or both. No series resistor is needed as 10kΩ resistors are already on the PCB. These will supply around 2mA which is sufficient for high-brightness LEDs but you can reduce the value if necessary, to drive less efficient LEDs. SC

# CIRCUIT NOTEBOOK

**Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.**




## 4-speed gear indicator uses a single 7-segment LED display

This circuit uses two switches in a gearbox to indicate which gear has been selected on a single 7-segment LED display driven by a CMOS 4511B BCD to 7-segment display chip, IC2. The table below shows the available inputs from the switches (X,Y) and the desired outputs (A,B,C).

| GEAR | Y | X | C | B | A |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 1 |
| 2 | 0 | 1 | 0 | 1 | 0 |
| 3 | 1 | 0 | 0 | 1 | 1 |
| 4 | 1 | 1 | 1 | 0 | 0 |

Clearly A is just the inverted X. B is only high when X or Y is high, but not both, so an exclusive-OR function is needed. For C to be high, both X and Y must be high or alternatively, both A and B must be low. The necessary decoding is achieved with CMOS 4070B quad XOR gate chip IC1, diodes D2 & D3 and a few resistors.

The 4511 BCD-to-7-segment display driver takes the three inputs (A, B, & C) and another (D) which is tied to ground. IC2 converts them for the 7-segment drive to DISP1 which must be a common cathode type.

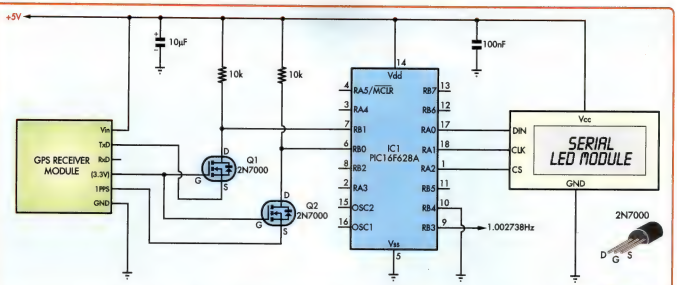
The Lamp Test (LT) and Blanking (Bl) inputs are tied high and Lamp Enable (EL) tied low for proper operation. Three diodes (D4, D5 & D6) are connected in series from the common cathode pin(s) of the display to ground and 3-position switch S3 allows the brightness to be changed to suit day or night-time driving.

The LM317 regulator removes any voltage spikes originating from the car's electrical system and the nominal 6V output can be adjusted between 5.5V and 8.2V so the Max/Min brightness ratio can be set as desired.

The segment outputs from the CD4511 can supply 10mA. Small displays (10mm) typically use one LED per segment while larger ones use two or more, so the supply voltage should be greater in those cases. Also green LEDs have a slightly higher drop across them and so require a slightly higher supply.

There is inbuilt electrostatic input protection for the CD4070 and the 100kΩ resistors to pins 2 & 6 of IC1 mean that full battery voltage can be applied. Also the 6.8kΩ resistors at the switches ensure that pins 2 & 6 can be tied to ground and are not left floating. LEDs 1 & 2 draw 2mA and are there to assist testing.

**Charles Tivendale, Edithvale, Vic. ($50)**




# Sidereal clock uses Arduino flight controller and display modules

This sidereal clock uses a u-blox NEO-6M Arduino GPS aircraft flight controller module, a PIC16F628A processor and an Arduino 8-digit red LED display module (with a MAX7219 serial driver). The power supply was cannibalised from a defunct radio, so the total cost was less than $25.

The 3.3V outputs of the GPS module are matched to the 5V input of the PIC with two 2N7000 FETs and two 10kΩ resistors. The displayed time updates within a tenth of a second of LMST (Local Mean Sidereal Time). This can be computed from the information in the NMEA data provided by a GPS unit (specifically the $GPRMC message, which has date, UTC time, and position).

A 1.002738Hz signal is available at the PIC's RB3 pin should it be needed. Pin RB4 is tied to logic low (ground) but if connected to logic high the display switches to UTC (Universal Coordinated Time. However, the RB3 signal continues regardless of which time is being displayed.

It would be feasible to display both UTC and LMST by daisy-chaining two MAX7219 modules and changing the software. The display of UTC or Mean Sidereal time will be accurate to within a few milliseconds. For visual purposes this should be close enough.

There are some limitations. The specified GPS has the antenna on board, so its positioning is an issue although it is reasonably sensitive for indoor use. There is no back-up battery, so it goes through a cold start on power up which can take some time. The MAX7219 (on the display module) can vary the LED brightness but it is fixed in the software to a low setting.

The output on RB3 is not symmetrical, about 10% high 90% low, and will jitter in the short term, from two sources: (1) the GPS provides slightly different longitudes each time and (2) granularity in the calculations. Both of these could be addressed but there is little point since the time is being displayed.

The software is based on the simplest calculation of mean sidereal time, one version being:

**LMST = (280.46061837 + 360.98564736629 * d + Long) mod 360**

where d = UT days since midnight on January 1st, 2000, including fractional days, giving LMST (Local Mean Sidereal Time) in degrees. This can be converted into time in sidereal seconds by multiplying by 240.

In operation, the software expects $GPRMC messages at 9600 baud and ignores any other messages. The message checksum is checked and corrupt messages are ignored. The $GPRMC message has a status field and only active (value 'A') messages are processed. The message must be preceded by a 1pps pulse and it is assumed that the time in the $GPRMC message is in whole seconds. The module I used satisfies this, and I think many other GPS units do too.

Alan Cashin is this month's winner of a $150 gift voucher from Rare & Forbes

At start-up, the CPU loops for about a second to be sure the MAX7219 is powered up. It then sends the message 'HELLO' to the display and this will stay until the GPS sends valid messages; then the time will be displayed. This can be minutes if the GPS module is doing a cold start.

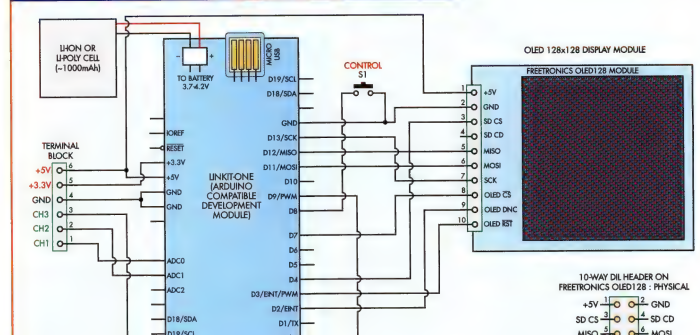
If a LED with a 4.7kΩ resistor is connected to RA3, it should show a 4Hz pulse from the end of the start-up loop onward. If it stops, either the CPU software or hardware is not operating.

If signal is lost once the time starts displaying, UTC will not be updated but the sidereal time will continue to update for a few seconds then stop. They will restart when good messages are received. If a leap second is inserted, it will not display as 23:59:60 but 00:00:00, and the next few seconds may be unreliable.

This site can be useful for checking calculations – see http://aa.usno.navy.mil/data/docs/siderealtime.php

The software file, designated *ClockV1.X.production.hex*, is on the SILICON CHIP website.

**Alan Cashin,**
**Islington, NSW.**




## A 3-channel data-logger with OLED display

This Arduino-compatible data-logger runs on the LinkIt One hardware and displays system status and values via an OLED display controllable with one pushbutton. The LinkIt One provides several modules built-in, such as GPS, RTC, on-board memory and WiFi. It also has provision to run off a single Lithium-ion or Lithium-polymer cell and to charge that cell from USB power.

The LinkIt One is connected to a Freetronics OLED display via a breakout shield. The shield is also fitted with a 6-way terminal block with connections to GND, +3.3V, +5V and CH1, CH2 & CH3. Channels 1 & 2 are analog inputs while channel 3 is a digital input or output with PWM capabilities.

The program logs the current channel values (after calculations) with a time stamp to a Comma-Separated Value (CSV) file which is stored on the LinkIt One's internal flash memory (although this can be changed to an SD card mounted on the OLED module). The files can be read by connecting to the USB port of a computer (after changing into Mass Storage Mode). Line 751 of the code determines when logging occurs, which is every half an hour by default – ie, when the minutes value is equal to 00 or 30. The actLogger function is then called to perform the calculations and write the data.

A separate log file is created for each day, in a separate folder. The file name format is "\datalogger\day\dd-mm-yyyy".

The screen is split into two parts, the title and the main area. When button S1 is pressed, what's displayed in the main area changes. The first and second screens display system information. This information is [First Screen] Battery Level (0, 33, 66 or 100%), Is Battery Charging (True/False), Last Log in minutes, Battery OK, Current GMT, [Second Screen] Uptime (Since last reboot), Time since battery was 100%, GPS Active (TRUE/FALSE) and GPS Synced (TRUE/FALSE).

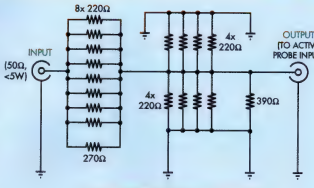
The third screen shows a live data feed from all three channels in both their raw form (direct from the analog or digital pins) and their calculated data (after mathematical formulas have been applied). The calculations for each can be set on lines 625 - 650 of the code. On the fourth (last) screen, the option to force a log entry is added. To force the unit to write data, hold down

## Attenuator for active probe unit

This circuit was devised to allow the Active RF Probe (SILICON CHIP, August 2013) to measure the output voltages of 5W UHF CB radios, using a 50-ohm dummy load, as well as using it for low-level signals. Our solution is to combine a 2:1 input divider with a 50-ohm dummy load (or perhaps with a centre-tapped 50-ohm dummy load).

The upper arm of the load/divider is made using nine 1206 SMD resistors in parallel; eight with a value of 220Ω and the ninth with a value of 270Ω, giving a total value of 24.96Ω. The lower arm of the load/divider is made from another nine 1206 SMD resistors in parallel; eight of them again with a value of 220Ω and with the ninth resistor having a value of 390Ω. This gives a total resistance of 25.68Ω which comes very close to 25.04Ω when shunted by the Active RF Probe's effective input resistance of 1Ω.

The end result is a dummy load with a value of 49.997Ω, combined with a voltage divider giving a division ratio very close to 2:1 (or -6dB) when connected to the input of the Active Probe. Because the UHF CB unit will deliver a power output of 5W, each of the resistors in the load/divider should dissipate no more than about 320mW and most 1206 SMD resistors should be able to withstand this for a minute or two, at least; 1206 resistors are typically rated for either 0.25W or 0.5W.




NOTE: ALL RESISTORS SHOULD BE 1% THICK FILM 1206 SMD TYPE, WITH A RATING OF 500mW

The load/divider can be housed in a small metal box, with the SMD resistors on a small piece of Veroboard or similar. With a good layout, this would keep the stray inductance and capacitance low and shouldn't have too much impact on the overall response.

**Jim Rowe,**
**SILICON CHIP.**

button S1 for at least 2.5 seconds.

When a long press is detected, the screen changes to an "attention" display before returning to screen four. A short press can be used to turn the screen off. This is a good idea since OLED displays can suffer from burn-in when left on the same display for extended periods of time.

When the battery level goes below 20%, a warning screen is displayed showing the battery level and time since last recharge. The unit is charged via the USB port at 5V and can last for approximately 24 hours on battery power with a 1000mAh cell. By adding a solar panel, solar regulator, 12V battery and a voltage regulator, the up-time can be virtually continuous.

To access log data, the device needs to be connected to a computer and the BOOTUP switch changed to Mass Storage. It will then appear as a 10MB drive on the computer.

After opening the datalogger folder, you can search for the data required. The format to search for is **dd-mm-yyyy** for day, **mm-yyyy** for month or **yyyy** for year. Each file is in CSV format so it can be read by most spreadsheet programs or opened in raw format with a word processor.

The program uses 99,992 bytes of 10,485,760 bytes maximum. The required libraries and software to program the board are the LinkIt One IDE (Integrated Development Environment) with SD card and FTOLED libraries. There is plenty of room in the coding to extend the device with WiFi or Bluetooth connectivity, GPS location logging and more.

The software file, designated *OLED_Datalogger_3CH.ino*, is on the SILICON CHIP website.

**Jed Hodgson,**
**Galong, NSW. ($75)**

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# Cheap programmer for the PIC32 microcontroller

By Robert Rozée, M.E. (EEE)

**Want to build a recent SILICON CHIP project that uses a PIC32? Great . . . but the prospect of programming a PIC32 can initially seem daunting. This minimal programmer will upload firmware into a PIC32 quickly and simply at very low cost.**

WITH THE DEMISE of parallel and "real" serial ports on PCs, getting code into Microchip's PIC processors has in recent years become more complicated and expensive. Way back in the 1990s, you only needed a few resistors and a transistor to build a low-cost PIC programmer, and hobbyists around the world spent many a joyful hour creating interesting gadgets with these little computers.

Sadly, those simple programmers no longer work with today's USB to serial bridge adapters and a PICkit 2 or PICkit 3 became essential. Then there is the large and somewhat complex MPLAB X IDE (400MB download) needed to drive Microchip's programmer.

These are somewhat daunting requirements for a user looking to program a single PIC for the first time. Compare this to the popular Arduino platform. Every Arduino board comes with a serial bootloader pre-installed, hence code can be uploaded directly via a serial or USB port without the need for a specialised programmer. The software to write, compile and upload this code (the Arduino IDE) is "only" an 80MB download. Which was great – for a while.

But then Geoff Graham released the Micromite – a complete BASIC computer on a PIC32 chip in a 28-pin DIP (SILICON CHIP, May 2014). It is significantly more poweful than most Arduinos but the higher cost of programming equipment is a drawback. While the blank chip for a Micromite costs less than US$5, uploading the Micromite firmware required a programmer costing as much as 10 times more. That isn't a big deal if you plan to program PICs frequently but it's a bit expensive as a one-off.

Hence a group of intrepid members from "The Backshed Forums" set about trying to create a cheaper, simpler alternative.

## The end result

At the end of this (somewhat lengthy) effort lay a new set of extensions to **pic32prog**, an existing open source (GPL) command-line utility written and maintained by Serge Vakulenko. It works with a range of commercial PIC programmers – including the PICkit 2 (but not 3). The latest release of **pic32prog** is now also able to use an Arduino Nano, using a protocol dubbed "ascii ICSP". Together with a few resistors and a 3.3V zener diode, this is sufficient to upload firmware to a PIC32. The total cost? Less than that of a single PIC32MX170 chip.

The Arduino hardware and "ascii ICSP" protocol are needed as an intermediate step. This is because, even though a modern PC has lots of computing power, limitations in the way USB is implemented prevent direct access to the control pins (RTS, CTS, DSR, DTR) of a USB-to-serial bridge at any reasonable speed.

Early attempts that connected directly between serial port pins and the target PIC32 resulted in programming times of several hours or extreme unreliability, whereas with an Arduino Nano in between, this time is cut to just a few minutes.

The "ascii ICSP" protocol is very simple, accepting single-character

## The PIC32 Processor Family

The PIC32 family of processors, made by Microchip Technology Inc, are powerful 32-bit system-on-chip (SoC) devices containing everything required to implement quite complicated computers that are as powerful as the first IBM PCs. This from a chip that is available in a 28-pin DIP, costs less than US$5, and can run from a pair of AA cells.

A number of SILICON CHIP projects in recent years have made use of PIC32 devices, including: the Colour Maximite (September 2012), GPS Tracker (November 2013), Micromite (May 2014, January 2015), and Nixie Tube Clock (February 2015).

The Micromite (PIC32MX170 chip + 47µF capacitor and 10kΩ resistor) is especially notable as it is programmed in BASIC, allowing the hobbyist to write simple code to realise almost any project without need for any sort of development environment beyond a serial terminal.

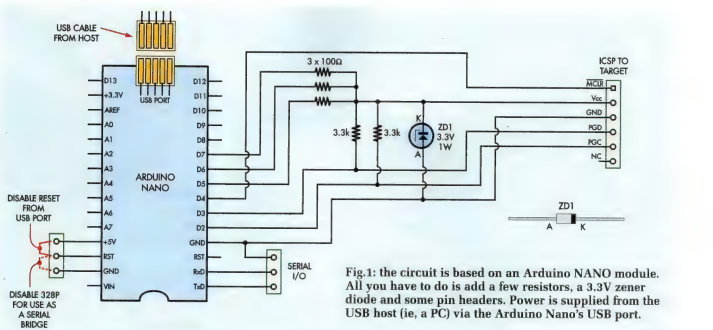



**Fig.1: the circuit is based on an Arduino NANO module. All you have to do is add a few resistors, a 3.3V zener diode and some pin headers. Power is supplied from the USB host (ie, a PC) via the Arduino Nano's USB port.**

## LOW-COST PIC32 PROGRAMMER USING AN ARDUINO NANO

ASCII commands from a host computer (running **pic32prog**) and converting these into the clock (PGC) and data (PGD) signals needed to program a PIC32. Lower case letters d, e, f, & g cause clocked output of the bit pairs 00, 01, 10, and 11 respectively, while upper case letters D, E, F & G clock out the same pairs, then read back one bit.

Other commands carry 4-bit pairs encoded as a single letter, assert and release the reset (-MCLR) pin and turn on/off the 3.3V supply to the target PIC32. Between PC and Arduino, serial communications occur at a brisk 115,200 baud.

### Hardware

The hardware is simple and cheap, the most expensive part being an Arduino Nano, widely and cheaply available via eBay. Three 100Ω resistors and a 3.3V zener diode create a switchable 3.3V supply for the PIC32 being programmed, capable of delivering up to 50mA ((5V - 3.3V) ÷ 33Ω) to the device. This load is shared across three pins on the Arduino, each capable of delivering 20mA.

Two more resistors (3.3kΩ) provide pull-ups for open-collector outputs that drive the two programming pins on the target PIC32 – PGC (clock) and PGD (data). These two pull-ups go to the 3.3V supply – while the Arduino Nano is a 5V device, most of the PIC32

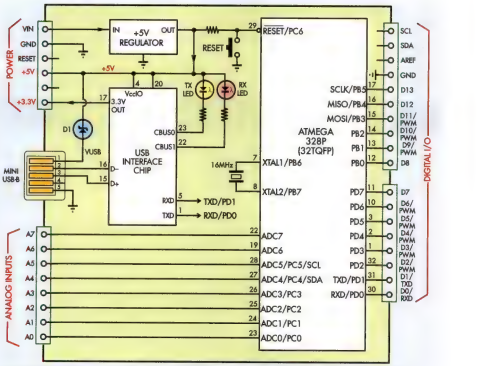



**Fig.2: block diagram of the Arduino Nano module. It's based on an Atmel ATmega328P microcontroller chip and a USB interface chip.**

pins should never have over 3.3V applied. No pull-up is fitted to the open-collector -MCLR (reset) output, as a 10kΩ pull-up should normally be present at the PIC32 end.

In operation, programming data is exchanged with the PIC32 in a 4-phase cycle. In phases 1 & 2, data (2 bits) is written to PGD. In phase 3, the direction of PGD is reversed to allow a single data bit to be read back from the PIC32, then in phase 4 the direction of PGD is reversed again.

Uploading the 250kB of Micromite firmware to a PIC32MX170 processor involves sending over three million

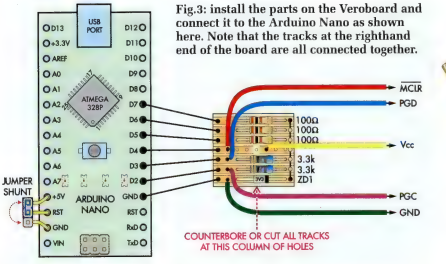
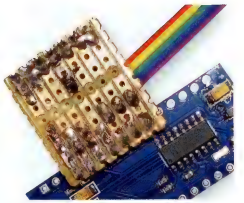



**Fig.3: install the parts on the Veroboard and connect it to the Arduino Nano as shown here. Note that the tracks at the righthand end of the board are all connected together.**



**The tracks on the underside of the Veroboard must all be cut as shown in this photograph.**

characters out the serial port and receiving half a million.

## Building it

The circuit is built on a small section of Veroboard attached to the side of the Nano, with a 5-way cable running up to a standard 6-pin ICSP plug. If desired, a LED and a 3.3kΩ series resistor can be connected across the 3.3V zener diode to show when the supply is turned on.

A 3-way header should also be fitted to the Arduino Nano board to allow linking its reset pin to ground or +5V. If the Arduino's reset pin is linked to ground, the onboard ATmega328P processor is disabled and the board can be used as a simple USB to serial bridge (via the "serial I/O" connector shown on the schematic). If reset is linked to +5V, the firmware on the Arduino is protected from being overwritten and the programmer will be detected more quickly when **pic32prog** is launched. **Do NOT install a jumper on these pins yet.**

Note: do not press the onboard reset button while the reset pin is linked to +5V, as doing so will short the USB port's +5V output to ground.

## Software

The only software required is the **pic32prog.exe** executable itself (versions 2.0.174 or later) that can be downloaded from the **pic32prog** source repository at GitHub:

**https://github.com/sergev/pic32prog**
**https://github.com/sergev/pic32prog/blob/master/pic32prog.exe?raw=true**

Note: the second link goes direct to the Win32 executable. Mac OS X and Linux versions are also available.

Drivers for the Arduino's USB to serial bridge may also be required for Windows XP and earlier. In the case of Chinese clones of the Arduino Nano currently available on eBay, it's likely that the bridge device used will be a CH430G, with drivers available from the manufacturer: **www.wch.cn/download/CH341SER_ZIP.html**

The Arduino IDE is not required for loading the "ascii ICP" firmware onto the Arduino Nano, as this function is performed by **pic32prog** internally. Once the USB drivers have been installed, simply open a command window at the folder where **pic32prog** is located. With the Arduino attached to a USB port but no target PIC32 connected, type:

```
pic32prog -d ascii:com5 -b3
```

where com5 is the serial port assigned to the Arduino, ascii is the name for the class of programmer ("ascii ICSP"), and -b3 tells **pic32prog** to upload the "ascii ICSP" firmware to the attached Arduino. This should display a message saying that firmware is being uploaded to the Arduino and will complete in a few seconds:

### Typical Programming Session

```
C>pic32prog -d ascii:com5 mm47b32.hex
Programmer for Microchip PIC32 microcontrollers, Version 2.0.174
    Copyright: (C) 2011-2015 Serge Vakulenko
        (ascii ICSP coded by Robert Rozee)

      Adapter: . OK1 OK2 - ascii ICSP v1E
    Processor: MX170F256B
 Flash memory: 256 kbytes
  Boot memory: 3 kbytes
         Data: 258692 bytes
        Erase: (90mS) done
  Loading PE: 1 2 3 4 (LDR) 5 6 7a (PE) 7b 8 v0301
Program flash: ######################################## done
 Program boot: ####### done
 Verify flash: ######################################## done
  Verify boot: ####### done
 Program rate: 2086 bytes per second

total TDI/TMS pairs sent = 3147141 pairs
total TDO bits received  = 459064 bits
total ascii codes sent   = 987417
total ascii codes recv   = 157828
maximum continuous write = 452 chars
O/S serial writes        = 95940
O/S serial reads (data)  = 14354
O/S serial reads (sync)  = 10
XferFastData count       = 58902
10mS delays (E/X/R)      = 9/0/0
elapsed programming time = 2m 06s
```

```
C>pic32prog -d ascii:com5 -b3
Programmer for Microchip PIC32
microcontrollers, Version 2.0.147
  Copyright: (C) 2011-2015 Serge
Vakulenko
    (ascii ICSP coded by Robert
Rozee)

57600 baud ... synchronized
Signature = 1e950f  Device =
ATmega328P
####################
Firmware uploaded to 'ascii ICSP'
adapter OK
```

If you see a row of dots after the "57600 baud" and a failure message, try repeating the process but this time press the Arduino's reset button while the dots are being written. If this also fails, try using -b1, -b2 or -b4 to select different Arduino bootloader baud rates. The vast majority of Arduino Nanos use a bootloader baud rate of 57,600 but there may be a few that use something different.

Note that the above step to upload the "ascii ICSP" firmware to the Arduino Nano need only be performed once. **You should then install a jumper between the reset and +5V pins**. You are then ready to upload the Micromite (or other) firmware to your PIC32.

## Using it

Place the firmware you want to upload in the same directory as **pic32prog** and open a command window at that location. Connect the target PIC32 to the programming hardware (Arduino).

The target PIC32 needs to have all its ground pins connected together, all $V_{DD}$ pins connected, a suitable capacitor between the Vcap pin and ground, and -MCLR pulled up to $V_{DD}$ via a 10kΩ resistor. It is essential that no ground or $V_{DD}$ pins be left disconnected.

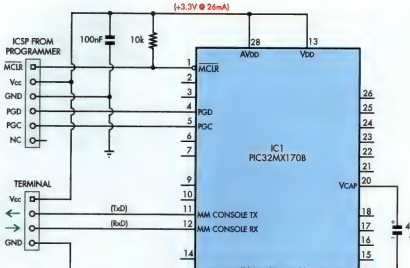



**Fig.4: before programming, the target PIC32 microcontroller needs to be wired in a manner similar to this example PIC32MX170B (check the pin connections for your particular PIC micro).**

An example schematic for the PIC-32MX170B 28-pin DIP is shown in Fig.4, including both ICSP and Micromite serial terminal connectors. The capacitor at Vcap should be a low-ESR type, such as chip ceramic or tantalum. If ceramic, the capacitor can be a 10µF part.

To upload the PIC32 firmware, type:

```
pic32prog -d ascii:com5 filename.hex
```

where filename.hex is the name of the firmware file. The programming hardware handles supplying power to the target PIC32, turning the 3.3V supply on before commencing programming and turning it off when completed.

Programming should take a few minutes, after which you can disconnect the programmer from your PIC32.

On very rare occasions, **pic32prog** can throw an error during programming – this is usually due to spurious behaviour within the target PIC32 triggered by electrical noise from the programming PC's power supply (especially if it's a laptop). If this happens, just reprogram the device a second time and the error will almost certainly not re-occur. Laptop computers can produce more electrical noise when running on AC power, so running off the battery may be prudent if issues arise.

## Conclusion

The combination of **pic32prog** and Arduino Nano provide a simple and cheap method for programming a PIC32 chip, albeit a bit more slowly than the PICkit 2/3 and without the integrated support in the MPLAB X IDE.

## Acknowledgements

(1) "ascii ICSP" protocol and hardware designed by Robert Rozée.
(2) "bitbang.c" extension for **pic32prog** written by Serge Vakulenko and Robert Rozée.
(3) The Backshed Forums: http://www.thebackshed.com/forum/forum_topics.asp?FID=16
(4) Full details of the "ascii ICSP" protocol are available in the file ICSP_v1E.ino at: https://github.com/sergev/pic32prog/tree/master/bitbang
(5) PIC32 programming details are from: "PIC32 Flash Programming Specification" (60001145N.pdf) SC

## Useful Batch Files: Open a Command Window & List Serial Ports

When using command-line utilities like pic32prog under Windows, there are a couple of batch files that are extremely useful to have sitting in the same folder. The first is a "command.bat" file, which, when double-clicked in a folder, will open a command window at that location. The "command.bat" file is as follows:

```
@prompt $n$g
@cmd
```

The other useful batch file to have around is "ports.bat" to list the available serial ports on a Windows PC. While there are more complicated solutions, the simplest means of obtaining this information is from the Windows registry using the following lines within the "ports.bat" batch file:

```
@reg query HKLM\hardware\devicemap\serialcomm
@pause
```

# When you want a REALLY close-up view . . .

by ROSS TESTER

**In the October issue of SILICON CHIP, our resident serviceman, Dave Thompson, waxed lyrical about the benefits of a USB microscope and its ability to obtain (extremely!) close-up views of a damaged PCB he was trying to repair. Talk about timing! We had recently decided to prepare a feature on "optical" service aids, including the exact device Dave was talking about. In fact, we had already received and photographed one of those USB microscopes, along with several other related items.**

**We had been planning** this feature for some time; that is ever since our esteemed Editor purchased a pair of high-magnification "glasses" on ebay.

Perhaps he should have known that the low price (around $6.00, including postage from China) would indicate that it wasn't going to be the world's greatest product . . . but we still have a surreptitious snigger when we remember his reaction upon opening them (we wouldn't dare laugh out loud!).

But we're getting ahead of ourselves: more on that stellar purchase a little later.

## OK, what were we really looking for?

Many readers, particularly those with . . . ahem . . . shall we say many years of experience, have taken us to task over our increasing use of SMD components.

"With my eyesight, I can't even see the little beggars, let alone read the labels" is a typical comment.

While most of us in the SILICON CHIP office can commiserate we're afraid it's not going to get any better in the future.

Many components are now only made in SMD format and even those that aren't tend to be significantly more expensive than SMDs. An increasing percentage of future projects will be at least partly based on SMDs. (Sorry!)

So it's basically a case of working around the problem or giving up the hobby. Of course, the latter is unthinkable for most enthusiasts, so there needs to be a solution. And magnification, so you *can* read the labels on the little beggars, is that solution.

If that were the beginning and end of the problem, all you would need is to arm yourself with a cheap magnifying glass you bought from the local bargain store. But it isn't as simple as that – many people with less than perfect eyesight also need illumination (and often strong illumination) as well as magnification.

Moreover, unless you have three or four hands, you can't hold a magnifying glass and the component and the soldering iron and the solder and the PCB . . . so ideally,

hands-free would be a blessing.

Let's see what's commonly available:

## Pro'sKit handheld LED Light Magnifier – Altronics X0430; $12.95 ea

We're going to start with a simple, hand-held magnifying glass (despite what we just said above, there are times when that is all that you really need).

Well, what we found is a bit more upmarket than a simple magnifying glass because this one also has twin LED illumination built in. That makes the handle a bit more bulky (to house the 3 x AAA batteries) but it's still very easy to hold and together with the relatively high magnification (3.5x) makes this nice to use in simple applications. The white LEDs throw a good light on the work area, too. It doesn't come with batteries so you'll need to add these before use.

Having said all that, we would have to rate this as being one of the less-useful magnifiers in all those we look at for this feature, with the possible exception of the next ones (which we call Leo's Follies)!

## "Glasses-Type Watch Repair Magnifier with LED Light" – ebay (from China), approx $6.00 including postage

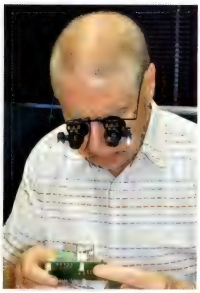
There were some choice undeleted expletives when these were unpacked. Of course, the description on ebay was glowing - "20x magnification power . . . loupe location adjustable on frame for your comfort . . . perfect for installing & repairing camera, watch, and other electronics. . .

So a pair was duly ordered and arrived some ten days later. That's when the fun began!

First of all, you'd hope that the two eyepieces would give a "binocular" effect; ie, combining into one. No way in the world – it gave two distinct images. Most disconcerting!

Second, while one of the magnifiers could be turned up and out of the way, that meant one eye is looking at a much magnified image while the other is not – at best, all we could do was close the non-magnified eye view so it wasn't so confusing. Most disconcerting II!

Third, the focal point of these was virtually right on the front lens – and there doesn't appear to be any logical or sensible way to adjust the operating distance or focus. Most disconcerting III!



Fourth, while the lens assemblies can be slid along the frame to account for different eye positions, it's not easy – they simply grab too tight to the frame so cannot be finely adjusted. Most disconcerting IV!

The good points? Yep, they're pretty cheap. Oh, the LEDs work (although finding CR1620 button cells to power them may not be quite as simple as it should be). Would we recommend them? You be the judge!

As night follows day, we're going to get someone ring and say that they use them all the time and they're a real beauty. Not us, though!

## Pro'sKit Headband Magnifier – Altronics T2555, $35.50

Now we're starting to get into the more professional gear. And if Leo swore about the Chinese glasses, he swears that these are the greatest thing since sliced bread (or maybe even before)!

What you get is not one or two but three different powers of magnification all fitted to an adjustable, comfortable headband. And when we say comfortable, it's not hard to forget that you have it on! The lens assembly can be adjusted in the vertical direction as required and similarly, the headband itself can be adjusted to suit your head size.

There is one set of lenses permanently mounted. These give a 1.8x magnification. That's not very much – about what you'd expect from a pair of reading glasses.

But mounted on a swing-down axle immediately behind the first lenses is a second pair, which gives a 2.6x magnification. That's highly useful in its own right for the vast majority of electronics tasks.

However, if that's not enough, there's a third lens which swings down over the right eye (only) which gives a significant 5.8x magnification. You might think it's a bit difficult having one eye at one level and the other at another – we found it easiest to simply close one eye if we needed the highest magnification.

### What else is the Headband Magnifier good for?

After having one of these in the home for just a few weeks, we've found a whole host of non-electronics uses for it – from removing splinters to picking up the dropped stitch in knitting. . . and everything in between. Would you believe they're also sensational for finding and removing ticks from children and animals; even hunting for head lice in the hair that the little darlings have managed to bring home from school!

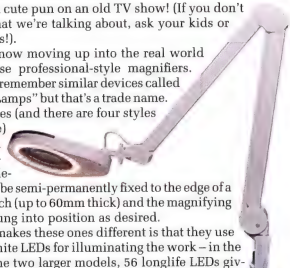
And if you need to work in low light, there's a pair of white LEDs mounted immediately above the lenses. Unlike most, these can be adjusted in both the vertical and horizontal directions to shine directly on the work. To change the two AAA batteries, the LED light source can be easily removed from the lenses. This also allows it to be used as a mini torch if you wish.

In summary, the Headband Magnifier is a bit more expensive than other types – but it's worth every cent!

## Inspect-a-gadget desk-mounted magnifiers – Altronics, Cat X4200, $109.00

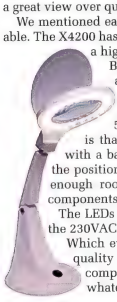
What a cute pun on an old TV show! (If you don't know what we're talking about, ask your kids or grandkids!).

We're now moving up into the real world with these professional-style magnifiers. You may remember similar devices called "Maggy Lamps" but that's a trade name. These ones (and there are four styles available) from Altronics are designed to be semi-permanently fixed to the edge of a workbench (up to 60mm thick) and the magnifying head swung into position as desired.



What makes these ones different is that they use bright white LEDs for illuminating the work – in the case of the two larger models, 56 longlife LEDs giving 3500-4500K natural white light. The magnifying glass itself is a rather large 130mm in diameter, giving a great view over quite a large area of work.

We mentioned earlier that there are four models available. The X4200 has a 3-dioptre lens, while the X4201 has a higher magnification 5-dioptre lens.



But there are also two "junior" versions at a significantly lower price – $54.95 – the X4204 has a 95mm diameter, 3-diotpre lens and the X-4205 has a 5-dioptre. The other main difference is that they are mounted on a heavy base with a balljoint on the 300mm stem to adjust the position. At this height, you have more than enough room underneath to be able to solder components, etc.

The LEDs in all these magnifiers operated from the 230VAC mains.

Which ever you choose, you're going to get a quality unit more than capable of identifying components, dry joints or broken tracks – or whatever else your application requires.

## Powered inspection units

All the magnifiers looked at so far are manual devices, that is, you look through a lens to see your work. But there are other, more esoteric devices now available which we alluded to at the start of this feature. These are the powered "cameras" which connect to your computer via the USB port and put their image on the computer screen.

While they operate in real time, they also have the ability to save what they "see" to the hard disk, flash drive, etc, for later close examination. Often, the faulty or suspect part reveals itself only on a more leisurely viewing, often with stop action as required.

We're looking at two devices which fit into this genre, although there are many, many more on the market.

## USB Digital Microscope – Altronics X4300A $55.00

As with the inspect-a-gadgets from Altronics, there is more than one model of these available. The specific one we're looking at here has a 200x zoom, 2-megapixel model which can take a variety of still images (in JPEG or bitmap) or video movies (in AVI).

It has a manual focus range, from a ring on the camera, of 10mm to 500mm and has eight brightness-adjustable LEDs for revealing dark, hidden secrets. The microscope is powered by the USB port it's plugged into.

As with the inspection camera above, a mini CD of software is supplied – for Windows 2000, XP, Vista and Win 7 (though we believe it will also work with 8 and 10) and, in this case, Mac 10.5 or higher.

That 10 to 500mm range gives you enormous scope (pardon the pun!) to examine a very wide range of equipment. And while it's rated at 2MP, the software interpolates that to 5MP so you really get some fine detail.

We mentioned other models: Altronics also have a 400x zoom, 1.3mp model for $79.95 (X4301), along with a brand new 200x zoom, 9mp model (X4304) for $145.00.

## 5MP USB Microscope Camera – Jaycar QC3199 $169.00

In some ways similar to the above model, the Jaycar Microscope Camera offers significantly manual focus from 10mm to 150mm, a shutter speed of 1 second to 1/1000s and still image resolution up to 2592 x 1944 pixels that's actually over 5MP).

It will also shoot video at 1280 x 960 pixels (which is also the lowest still image resolution.

Its built-in light source is eight ultrabright white LEDs

which, while they certainly light up the subject, we found were a little distracting when trying to view anything with a shiny or reflective surface (eg, a PCB!). There were eight high-brightness spots surrounding our image which no amount of LED level adjustment would eliminate.

This microscope/camera is very similar in shape and size to the Altronics model; the biggest difference we could find (apart from the optics) is that the "trigger" button (to take a picture) is rather more conveniently located on the cable, not on the microscope body.

It also comes with a rather larger (and heavier) "professional" baseplate, intended to minimise vibration and movement. The baseplate is fitted with two spring object holders as well.

The mounting pillar allows the microscope to be turned through 180°, allowing "off baseplate" shots while maintaining the security that the heavy baseplate offers.

There's a course focus adjustment provided on the mounting stand and a fine adjustment on the microscope body.

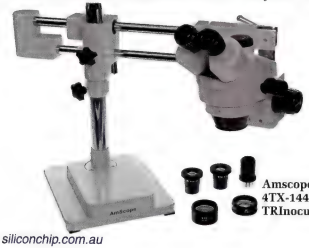
Once again, it's powered by the USB port into which it is plugged and the specs state it will work with Windows XP/Vista/7 & 8, along with Mac 10-6-10.9. We also proved that it works perfectly with Windows 10.

A CD of software is included which came up without drama and allowed the driver to be installed without fuss.

It's more expensive than the Altronics model but with that heavy (they call it "professional"!) base it does feel slightly sturdier.

## What else is out there?

Tonnes! Literally – we've only scraped the surface of these devices – and we've deliberately kept in the low end of the market because that's what most hobbyists would be looking for.



**Amscope's 4TX-144A TRInocular.**

But there are many more "professional" models out there as well, many with professional price tags. For example, in the July 2014 issue Andrew Levido reviewed an Amscope 4TX-144A Trinocular microscope – along with the two "binocular" eyepieces, it had a third port for mounting a digital camera (**www.amscope.com**).

But at a (then) price of almost $1000 – and we know what has happened to the dollar since – it is probably out of reach of most hobbyists. However, if your livelihood depends on such a device, it could be great value!

## But if you REALLY want to get serious . . .

While we were preparing this mini-feature, Hawker Richardson sent us details of their Mantis Elite stereo camera.

Now let's get one thing out of the way immediately: this is NOT for hobbyist users. It's unashamedly intended for all day, every day production and service applications, etc, where it is vital that the camera doesn't contribute to operator fatigue (and therefore mistakes).

It's *very* expensive compared to all the other cameras shown here – in fact, just to buy most of the lenses for the Mantis Elite you'd spend significantly more than any of the other cameras (yes, the lenses are "optional" extras!

The difference between this camera and virtually ALL others is that, while it offers stereo vision, you don't have to peer through a pair of eyepieces (which can be very tiring).

Instead, there's an internal video screen which offers a hi-res (HD) image of the work below.

A USB-equipped model is available but the base model retails for almost $3500 plus GST, PLUS the universal stand (another $862+) and not forgetting the lens (ranging from $205 [for 2x magnification] through to a pretty significant $1150+ for the x15 lens – though strangely, the x20 is about half this price!).

So with a midrange lens, you'll be up for more than $5000 for the Mantis Elite. If your livelihood depends on it, though . . .

If you want to know more, our old friend David Jones has an in-depth review on his EEV Blog website (access via the Hawker Richardson website).

David was in raptures, by the way! And as he says, you're going to need to try one of these out for yourself before plonking down that amount of cash. Fortunately, Hawker Richardson will come to you for a demonstration.

Contact Hawker Richardson on 1300 36 00 31, or via their website **www.hawkerrichardson.com.au/shop/optical-inspection-products/product/34-mantis-elite-cam-hd**.

# Vintage Radio

By Ian Batty

## The General Electric P-807 5-Transistor Set

**The P-807, General Electric's second transistor radio, still had only five transistors just like the earlier model 675. However, unlike the model 675, it used a fixed bias Class-A output stage and other aspects of the circuit were also quite different.**

AS DETAILED in the September 2015 issue, Thomas Edison's many technology companies had consolidated into the Edison Electric Light Company by 1889. And this in turn eventually amalgamated with the Thomson-Houston Electric Light Company to form General Electric in 1892.

In common with several other electronics manufacturers during World War II, GE worked on microwave diodes for use in radar receiver mixers. Following the war, the company eventually decided to get into transistor manufacturing and June 1st, 1951 saw GE list their point-contact SX-4A and Z2 types. In today's dollars, these transistors cost around $480 each.

Intensive development by Hall at the Schenectady centre and Saby at Syracuse eventually produced (respectively) the grown-junction type (as also produced by Texas Instruments for the Regency TR-1) and the alloyed-junction type. The latter was released as the 2N43/44/45 in 1953 and this type dominated the industry until the arrival of advanced diffusion techniques.

Their Philips/Mullard cousins, the lower-powered OC70/71, are the types we are more familiar with in Australia. For a complete history, see the article by Mark P. D. Burgess as listed in the references in the September issue.

All germanium devices are vulnerable to surface contamination. Native germanium will naturally oxidise to form a surface layer but germanium dioxide is not impervious to attack. Silicon dioxide, though, is basically glass. This meant that manufacturers could "top off" silicon devices with an oxide layer and be sure of reliability.

### 2N170: normal & "top hat"

Many of GE's early transistors used a "top hat" outline, as shown in an accompanying photograph. Much of GE's early output was for the military and so reliability was critical. As a result, early GE transistors featured a top "exhaust port" and this allowed the metal-cased transistors to be completely evacuated during manufacture to ensure the best possible reliability.

### Comparison/highlights/design

As with the GE 675 radio described in the September 2015 issue, the P-807 featured here is a 5-transistor design. However, there are important differences between the two.

First, as noted, the GE-675 uses an ingenious "sliding bias" volume control/bias circuit for the output stage. By contrast, the P-807 uses a conventional diode demodulator and fixed bias on the Class-A output stage. In addition, unlike the GE 675, the P-807's first IF amplifier stage is wired in a grounded base configuration, while the loudspeaker uses a moving-armature/reed motor to drive the speaker cone.

This type of speaker is known as a moving-iron loudspeaker. Basically, it consists of a solenoid and a thin ferrous-metal diaphragm which is attached to the cone. When an audio signal is applied to the solenoid, the solenoid's magnetic field varies and the diaphragm (or reed) moves in response to this varying magnetic field.

As noted previously, a 5-transistor design may seem like a recipe for poor performance. However, it's worth re-

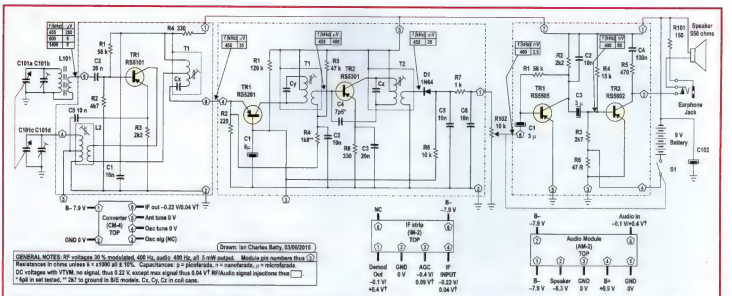
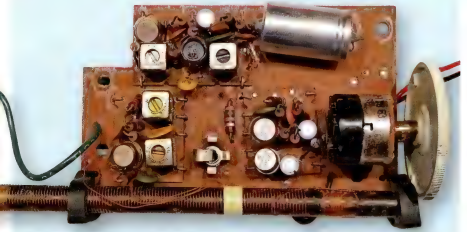



**Fig.1: GE P-807 is a 5-transistor superhet design. The G, H, S & T models were based on three modules – one for the converter stage, another for the IF strip and the third for the audio amplifier. Note that the audio amplifier uses a Class-A output stage.**



**The three modules used in the P807 are soldered directly to a larger PCB. In this photo, the converter module is at bottom left, the IF stage is at top centre, and the audio amplifier module is at bottom right, immediately to the left of the volume control pot.**

membering that a conventional 6-transistor set has only five amplifying stages, since two of its six transistors are used in a push-pull output amplifier stage. By contrast, both the GE-675 and P-805 sets use a Class-A output stage when uses just a single transistor.

## P807: first look

When I first opened the P-807's back and checked the circuit board, there didn't appear to be enough tracks for a 5-transistor superhet design. Removing the board and flipping it over solved the riddle. Versions P-807G, H, S & T use three soldered-in modules: one for the converter stage, another for the IF strip and a third for the audio stage.

Basically, the set described here is an upgrade of the original P-807B/E models which used a conventional PCB, with all components mounted directly on it.

At first glance, modular design sounds attractive. Instead of an exhaustive component-level troubleshooting procedure, one simply identifies and swaps out the faulty module.

However, this approach does rely on the availability of replacement modules. In practice, specialised spare parts such as these become harder to obtain as the years go by and in this case, a quick online search turned up nothing. This means that any repairs (other than to the antenna rod, tuning gang or speaker) generally require careful removal of the offending module so that component-level repairs can be carried out.

## Circuit description

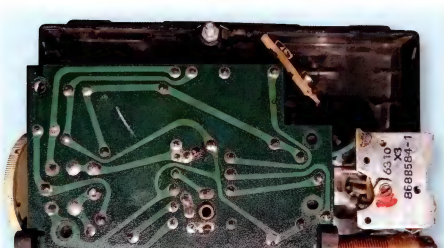
The GE-675 was the most unusual transistor radio design I'd previously encountered, so what surprises did the P807 have in store? Before we delve into the circuit, note that the following description is for the modular version, so each module has its own part numbering. The previous "all on one board" circuit uses a common numbering scheme.

In particular, note that the transistor, capacitor and resistor numbers start over again on each module (eg, there's a TR1 on the converter module, a TR1 on the IF module and a TR1 on the audio amplifier module).

Fig.1 shows the circuit details of the P807. The converter stage is quite conventional with collector-base feedback for TR1 via oscillator coil L1. It's similar to that used in the GE-675 but has slightly different biasing values due to a lower 9V supply. In addition, TR1's collector load is a single, tapped tuned winding in the 1st IF transformer (T1). By contrast, the GE-675 uses a conventional double-coil IF transformer here.

## IF module

The first IF amplifier is based on TR1 (in the IF module) and, as mentioned above, this is connected as a common base circuit. This circuit is sometimes preferred for its ability to work well at both VHF and UHF frequencies. Its



**The three modules used in this P-807 mean that the track layout on the main PCB is relatively simple. Note the large tuning gang at right.**

main advantage is the virtual elimination of feedback capacitance, an advantage that also applies to grounded-grid valve circuits.

Its main disadvantage is lower power gain than from a well-neutralised common-emitter stage. Although a grounded-base configuration can give substantial voltage gain, its current gain is less than unity. By contrast, a common-emitter stage can provide current gain as well as voltage gain and that means that its power gain is higher.

Note that although signal injection voltages and antenna field strengths are quoted in microvolts per metre, the critical issue in transistor amplifier stages is power gain. As a result, there is a near-universal preference for the common-emitter configuration in all but VHF/UHF applications.

Unlike the 675, AGC is applied to the 1st IF amplifier stage (TR2) via its base bias circuit. In this case. AGC is derived from the output of detector diode D1 and fed back to TR1's base via resistor R6.

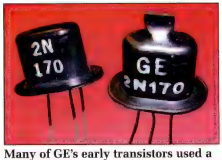
The output from the 1st IF amplifier feeds the tapped, tuned primary of the 2nd IF transformer (T1). Its untapped, untuned secondary then feeds the second IF amplifier stage based on PNP transistor TR2.

As shown in Fig.1, TR2 is connected as a conventional common-emitter stage and is neutralised via capacitor C4. This IF amplifier stage in turn feeds the untapped tuned primary of the 3rd IF transformer T2. Its untuned, untapped secondary then feeds diode demodulator D1 which then feeds the audio amplifier. D1 also provides the AGC voltage for the 1st IF amplifier (TR1) and, as mentioned above, this is fed back via resistor R6.

There's just one final detail: TR2 is also gain-controlled, as its base bias is affected by TR1's emitter voltage. Think of TR1 as an emitter-follower – it feeds the varying AGC voltage at its base out via its emitter to the bottom end of TR2's bias divider which uses resistors R4 and R5. Note that this happens in the modular versions only; the B & E models lack this gain-control connection.

## Audio amplifier

The first audio stage is based on TR1 and uses simple collector bias (R1 & R2). As shown on Fig.1, the detected audio from D1 is fed to TR1's base via volume control R102 (a 10kΩ pot) and capacitor C1. The resulting signal on TR1's collector is then fed to the base of output stage TR2 via capacitor C3.




**Many of GE's early transistors used a "top hat" case with an exhaust port as shown on the right. The exhaust port allowed the metal-cased transistors to be completely evacuated during manufacture to ensure maximum reliability.**

Output stage TR2 works with fixed bias, possibly because the sliding bias circuit used in GE's 675 model (see SILICON CHIP, September 2015) was unreliable and didn't offer thermal protection.

At first glance, TR2 appears to lack an emitter resistor which would make it prone to thermal runaway. However, closer examination shows that the main 9V supply's dropping resistor (R6) is also TR2's emitter resistor, and it's bypassed using C102. And that's clever – we get a combination of bias and emitter and supply bypassing in one circuit.

The stability is also aided by the fact that TR2 operates as a Class-A stage and thus has constant current drain. By contrast, the varying current drain of a Class-B output stage can be a recipe for audio instability without the necessary precautions.

## Moving-iron speaker motor

Output stage TR2 directly drives a magnetic speaker with an impedance of 550Ω. The speaker used is a moving-iron type, a design that was common and popular in the early days of radio. This type of speaker is capable of driving a large cone to moderate volumes and replaced the earlier horn types.

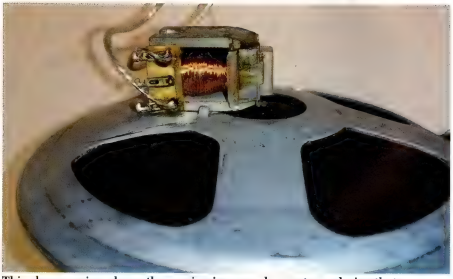
While a moving-iron speaker can give adequate living-room volume levels, its restricted frequency response and limited power-handling capabilities eventually saw it overtaken by the moving-coil speaker. These can be made with a wide frequency response and power handling capabilities up to hundreds of watts and remain the dominant type today.

## The author's GE P-807

I recently purchased a GE P-807 and when I applied power, I was rewarded with a perfectly-operating set. A quick spin of the dial brought in plenty of stations, so a quick clean and polish was all I needed to do to restore the set.

So how good is it? The answer is pretty good. Although it lacks the sliding-bias "battery miser" output stage design of the 675 model, it's a better radio all round. What's more, it runs from a single 9V battery and this makes it a more attractive vintage set than some other early transistor radios.

Its audio response from volume



**This close-up view shows the moving-iron speaker motor, a design that was common in the early days of radio. This one has an impedance of 550Ω.**

control to loudspeaker is 40Hz – 3kHz at the -3dB points and out to around 10kHz at -10dB. The response from antenna to speaker is around 45Hz – 1.5kHz, while the IF selectivity is ±2.5kHz at -3dB and ±30kHz at -60dB.

In practice, its audio performance is better than the 675's, with a maximum output of 60mW at clipping. At 5mW output, the distortion is 3.2% (6% at 50mW).

The set's RF sensitivity is 50μV/m at 600kHz and 90μV/m at 1400kHz but with a S/N ratio of only 10dB. In order to achieve a 20dB S/N ratio, it requires around 70μV/m at 600kHz and 130μV/m at 1400kHz.

The 2-stage AGC is outstanding, there being only a 6dB increase in the output in response to a 40dB signal increase. I also monitored TR2's base voltage in the IF module during testing and found that it dropped from about 0.5V to 0.3V in the presence of strong signals, thus confirming the operation of the 2-stage AGC circuitry. During these tests, I also discovered that I had to apply some 200mV/m of signal before the IF channel began to distort the signal due to overload.

## Loudspeaker performance

Compared to similar sets with moving-coil speakers, the P807 performs pretty well with its moving iron speaker. Applying a pink noise signal to the audio section resulted in an acoustic response from 200Hz to 3.5kHz at -10dB, with a pronounced peak around 3kHz.

This confirms the moving-magnet mechanism's problem with mechanical resonance. For such a small set though, it's a minor quibble.

## How it compares

This is a well-designed little set. Compared to the outstanding Philips 198, with its 6-transistor design and Class-B audio output stage, the GE P-807's lower audio output (about -5dB down) suffers only in very noisy environments. In the workshop, there really isn't much difference between them.

As stated, a 5-transistor set with a Class-A output stage has the same number of amplifying stages as a 6-transistor set with a Class-B output stage. As a result, it follows that their sensitivity and audio quality at moderate volume levels are pretty similar.

The P-807 does, however, have higher current consumption than similar sets, at around 20-25mA for all volume settings. By contrast, the GE-675 varies its current consumption with volume due to its sliding-bias Class-A output stage, while Class-B sets also vary their current with volume.

So would I buy another one? The answer is maybe. Until I came across this set, I had been unaware of the two different methods used to build the various models; ie, the P-807B/E models used all discrete components, while the P-807G/H/S/T series used the 3-module approach. Apart from servicing issues, it would be nice to know whether the modular construction technique offered any advantages.

Finally, as with the GE-675, P-807s are often available on eBay, usually from the United States.

## Further reading

(1) For information on the P-807B/E non-modular sets, see: **http://www.antiqueradios.com/forums/viewtopic.php?f=4&t=224244** where you'll find links to the Sams P-807 Photofact under a post by PBPP.

(2) For information on the G/H/S/T modularised versions, see: **http://www.radiomuseum.org/r/general_el_p807sp_807.html**

(3) For information on the moving-iron speaker, see: **https://en.wikipedia.org/wiki/Moving_iron_speaker** SC

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## HERE'S HOW TO ORDER:

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**Via the INTERNET** (24 hours, 7 days)
Log on to our secure website: siliconchip.com.au, click on "SHOP" and follow the links

**Via EMAIL** (24 hours, 7 days)
email silicon@siliconchip.com.au – Clearly tell us what you want and include your contact and credit card details

**Via MAIL** (24 hours, 7 days)
PO Box 139, Collaroy NSW 2097. Clearly tell us what you want and include your contact and credit card details

**Via PHONE** (9am-5pm EADST, Mon-Fri)
Call (02) 9939 3295 (INT 612 9939 3295) – have your order ready, including contact and credit card details!

**YES! You can also order or renew your SILICON CHIP subscription via any of these methods as well!**

## PRE-PROGRAMMED MICROS

Price for any of these micros is just $15.00 each + $10 p&p per order#

As a service to readers, *Silicon Chip OnLineShop* stocks microcontrollers and microprocessors *used in new projects* (from 2012 on) and some selected older projects – pre-programmed and ready to fly!

*Some micros from copyrighted and/or contributed projects may not be available.*

| | |
|---|---|
| **PIC12F675-I/P** | UHF Remote Switch (Jan09), Ultrasonic Cleaner (Aug10), Ultrasonic Anti-fouling (Sep10), Cricket/Frog (Jun12) Do Not Disturb (May13) |
| **PIC16F1507-I/P** | IR-to-UHF Converter (Jul13), UHF-to-IR Converter (Jul13) PC Birdies "2 chips – $15 pair" (Aug13). Driveway Monitor Receiver (July15) Wideband Oxygen Sensor (Jun-Jul12) |
| **PIC16F88-E/P** | Hi Energy Ignition (Nov/Dec12), Speedo Corrector (Sept13), Auto Headlight Controller (Oct13) 10A 230V Motor Speed Controller (Feb14) |
| **PIC16F88-I/P** | Projector Speed (Apr11), Vox (Jun11), Ultrasonic Water Tank Level (Sep11), Quizzical (Oct11) Ultra LD Preamp (Nov11), 10-Channel Remote Control Receiver (Jun13), Revised 10-Channel Remote Control Receiver (Jul13), Nicad/NiMH Burp Charger (Mar14) Remote Mains Timer (Nov14), Driveway Monitor Transmitter (July15) Fingerprint Scanner (Nov15) |
| **PIC16LF88-I/P** | Garbage Reminder (Jun13), Bellbird (Dec13) |
| **PIC16LF88-I/SO** | LED Ladybird (Apr13) |
| **PIC16F877A-I/P** | 6-Digit GPS Clock (May-Jun09), Lab Digital Pot (Jul10) Semitest (Feb-May12) |
| **PIC18F2550-I/SP** | Batt Capacity Meter (Jun09), Intelligent Fan Controller (Jul10) |
| **PIC18F45K80** | USB Power Monitor (Dec12) |
| **PIC18F4550-I/P** | GPS Car Computer (Jan10), GPS Boat Computer (Oct10) |
| **PIC18F14K50** | USB MIDIMate (Oct11) |
| **PIC18F27J53-I/SP** | USB Data Logger (Dec10-Feb11) |
| **PIC18LF14K22** | Digital Spirit Level (Aug11), G-Force Meter (Nov11) |
| **PIC32MX795F512H-80I/PT** | Maximite (Mar11), miniMaximite (Nov11), Colour Maximite (Sept/Oct12), Touchscreen Audio Recorder (Jun/Jul14) |
| **PIC32MX170F256B-50I/SP** | Micromite Mk2 (Jan15) – *also includes FREE 47µF tantalum capacitor* |
| **PIC32MX170F256B-I/SP** | Low Frequency Distortion Analyser (Apr15) Bad Vibes (June 15) |
| **PIC32MX170F256D-50I/PT** | 44-pin Micromite Mk2 (Now with Mk2 Firmware at no extra cost) |
| **PIC32MX250F128B-I/SP** | GPS Tracker (Nov13) Micromite ASCII Video Terminal (Jul14) |
| **PIC32MX470F512H-I/PT** | Stereo Audio Delay/DSP (Nov13), Stereo Echo/Reverb (Feb 14), Digital Effects Unit (Oct14) |
| **dsPIC33FJ128GP802-I/SP** | Digital Audio Signal Generator (Mar-May10), Digital Lighting Controller (Oct-Dec10), SportSync (May11), Digital Audio Delay (Dec11) Level (Sep11) Quizzical (Oct11), Ultra-LD Preamp (Nov11), LED Musicolor (Nov12) |
| **dsPIC33FJ64MC802-E/P** | Induction Motor Speed Controller (revised) (Aug13) |
| **dsPIC33FJ128GP306-I/PT** | CLASSIC DAC (Feb-May 13) |
| **ATTiny861** | VVA Thermometer/Thermostat (Mar10), Rudder Position Indicator (Jul11) |
| **ATTiny2313** | Remote-Controlled Timer (Aug10) |

When ordering, be sure to nominate BOTH the micro required AND the project for which it must be programmed.

## SPECIALISED COMPONENTS, HARD-TO-GET BITS, ETC

P&P – $10 Per order#

**ARDUINO-BASED ECG SHIELD** - all SMD components (*Oct 15*) **$25.00**
**ULTRA LD MK 4** - plastic sewing machine bobbin for L2 – pack 2 (*Oct 15*) **$2.00**

**VOLTAGE/CURRENT/RESISTANCE REFERENCE** - all SMD components# (*Aug 15*) **$12.50**
*# includes precision resistor. Specify either 1.8V or 2.5V*

**MINI USB SWITCHMODE REGULATOR** all SMD components (*July 15*) **$10.00**

**BAD VIBES INFRASOUND SNOOPER** - TDA1543 16-bit Stereo DAC IC (*Jun 15*) **$2.50**

**BALANCED INPUT ATTENUATOR** - all SMD components inc.12 NE5532D ICs, 8 SMD diodes, SMD caps, polypropylene caps plus all 0.1% resistors (SMD & through-hole) (*May 15*) **$65.00**

**APPLIANCE INSULATION TESTER** - 600V logic-level Mosfet. 5 x HV resistors: (*Apr15*) **$10.00**

**ISOLATED HIGH VOLTAGE PROBE** - Hard-to-get parts pack: all ICs, 1N5711 diodes, LED, high-voltage capacitors & resistors: (*Jan15*) **$40.00**

**CDI** – Hard-to-get parts pack: Transformer components (excluding wire), all ICs, Mosfets, UF4007 diodes, 1µF X2 capacitor: (*Dec 14*) **$40.00**

**CURRAWONG AMPLIFIER** Hard-to-get parts pack: (*Dec 14*) **$50.00**
LM1084IT-ADJ, KCS5603D, 3 x STX0560, 5 x blue 3mm LEDs, 5 x 39µF 400V low profile capacitors

**ONE-CHIP AMPLIFIER** - All SMD parts (*Nov 14*) **$15.00**

**DIGITAL EFFECTS UNIT** WM8371 DAC IC & SMD Capacitors *[Same components also suit Stereo Echo & Reverb, Feb14 & Dual Channel Audio Delay Nov 14]* (*Oct14*) **$25.00**

**AD8038ARZ Video Amplifier ICs** (SMD)
For Active Differential Probe (Pack of 3) (*Sept 14*) **$12.50**

**44-PIN MICROMITE** Complete kit inc PCB, micro etc (*Aug14*) **$35.00**

**MAINS FAN SPEED CONTROLLER** - AOT11N60L 600V Mosfet (*May14*) **$5.00**

**RGB LED STRIP DRIVER** - all SMD parts and BSO150N03 Mosfets, does not include micro (see above) nor parts listed as "optional" (*May14*) **$20.00**

**HYBRID BENCH SUPPLY**- all SMD parts, 3 x BCM856DS & L2/L3 (*May 14*) **$45.00**

**USB/RS232C ADAPTOR** MCP2200 USB/Serial converter IC (*Apr14*) **$7.50**

**NICAD/NIMH BURP CHARGER** (*Mar14*) **$7.50**
1 SPD15P10 P-channel logic Mosfet & 1 IPP230N06L3 N-channel logic Mosfet

**10A 230V AC MOTOR SPEED CONTROLLER** (*Feb14*) **$45.00**
40A IGBT, 30A Fast Recovery Diode, IR2125 Driver and NTC Thermistor

**GPS Tracker** MCP16301 SMD regulator IC and 15µH inductor (*Nov13*) **$5.00**

**SMD parts for SIDRADIO** (*Oct13*) **$20.00**
Same as LF-UP Upconverter parts but includes 5V relay and BF998 dual-gate Mosfet.

**RF Probe** All SMD parts (*Aug13*) **$5.00**

**LF-HF Up-converter** Omron G5V-1 5V SPDT 5V relay (*Jun13*) **$2.00**

**"LUMP IN COAX" MINI MIXER** SMD parts kit: (*Jun13*) **$20.00**
Includes: 2 x OPA4348AID, 1 x BQ2057CSN, 2 x DMP2215L, 1 x BAT54S, 1 x 0.22Ω shunt

**LF-HF UP-CONVERTER** SMD parts kit: (*Jun13*) **$15.00**
Includes: FXO-HC536R-125 and SA602AD and all SMD passive components

**THESE ARE ONLY THE MOST RECENT MICROS AND SPECIALISED COMPONENTS. FOR THE FULL LIST, SEE www.siliconchip.com.au/shop**

*All items subject to availability. Prices valid for month of magazine issue only. All prices in Australian dollars and included GST where applicable. # P&P prices are within Australia. O'seas? Please email for a quote*

11/15

# PRINTED CIRCUIT BOARDS

**NOTE: The listings below are for the PCB only** – *not a full kit!*. If you want a kit, contact the kit suppliers advertising in this issue. For more unusual projects where kits are not available, some have specialised components available – see the list opposite.

| PRINTED CIRCUIT BOARD TO SUIT PROJECT: | PUBLISHED: | PCB CODE: | Price: |
|---|---|---|---|
| VOX | JULY 2011 | 01207111 | $20.00 |
| ELECTRONIC STETHOSCOPE | AUG 2011 | 01108111 | $10.00 |
| DIGITAL SPIRIT LEVEL/INCLINOMETER | AUG 2011 | 04108111 | $10.00 |
| ULTRASONIC WATER TANK METER | SEP 2011 | 04109111 | $20.00 |
| ULTRA-LD MK2 AMPLIFIER UPGRADE | SEP 2011 | 01209111 | $5.00 |
| ULTRA-LD MK3 AMPLIFIER POWER SUPPLY | SEP 2011 | 01109111 | $15.00 |
| HIFI STEREO HEADPHONE AMPLIFIER | SEP 2011 | 01309111 | $20.00 |
| GPS FREQUENCY REFERENCE (IMPROVED) | SEP 2011 | 04109073 | $30.00 |
| HEARING LOOP RECEIVER/NECK COUPLER | SEP 2011 | 01209101 | $10.00 |
| DIGITAL LIGHTING CONTROLLER LED SLAVE | OCT 2011 | 16110111 | $30.00 |
| USB MIDIMATE | OCT 2011 | 23110111 | $25.00 |
| QUIZZICAL QUIZ GAME | OCT 2011 | 08110111 | $25.00 |
| ULTRA-LD MK3 PREAMP & REMOTE VOL CONTROL | NOV 2011 | 01111111 | $30.00 |
| ULTRA-LD MK3 INPUT SWITCHING MODULE | NOV 2011 | 01111112 | $10.00 |
| ULTRA-LD MK3 SWITCH MODULE | NOV 2011 | 01111113 | $10.00 |
| ZENER DIODE TESTER | NOV 2011 | 04111111 | $20.00 |
| MINIMAXIMITE | NOV 2011 | 07111111 | $10.00 |
| ADJUSTABLE REGULATED POWER SUPPLY | DEC 2011 | 18112111 | $5.00 |
| DIGITAL AUDIO DELAY | DEC 2011 | 01212111 | $25.00 |
| DIGITAL AUDIO DELAY Front & Rear Panels | DEC 2011 | 01212112/3 | $20 per set |
| AM RADIO | JAN 2012 | 06101121 | $10.00 |
| STEREO AUDIO COMPRESSOR | JAN 2012 | 01201121 | $30.00 |
| STEREO AUDIO COMPRESSOR FRONT & REAR PANELS | JAN 2012 | 01201127-1/2 | $20.00 |
| 3-INPUT AUDIO SELECTOR (SET OF 2 BOARDS) | JAN 2012 | 01101121-1/2 | $30 per set |
| CRYSTAL DAC | FEB 2012 | 01102121 | $20.00 |
| SWITCHING REGULATOR | FEB 2012 | 18102121 | $5.00 |
| SEMTEST LOWER BOARD | MAR 2012 | 04103121 | $40.00 |
| SEMTEST UPPER BOARD | MAR 2012 | 04103122 | $40.00 |
| SEMTEST FRONT PANEL | MAR 2012 | 04103123 | $75.00 |
| INTERPLANETARY VOICE | MAR 2012 | 04102121 | $10.00 |
| 12/24V 3-STAGE MPPT SOLAR CHARGER REV.A | MAR 2012 | 14102112 | $20.00 |
| SOFT START SUPPRESSOR | APR 2012 | 10104121 | $10.00 |
| RESISTANCE DECADE BOX | APR 2012 | 04104121 | $20.00 |
| RESISTANCE DECADE BOX PANEL/LID | APR 2012 | 04104122 | $20.00 |
| 1.5kW INDUCTION MOTOR SPEED CONT. (New V2 PCB) | APR (DEC) 2012 | 10105122 | $35.00 |
| HIGH TEMPERATURE THERMOMETER MAIN PCB | MAY 2012 | 21105121 | $30.00 |
| HIGH TEMPERATURE THERMOMETER Front & Rear Panels | MAY 2012 | 21105122/3 | $20 per set |
| MIX-IT! 4 CHANNEL MIXER | JUNE 2012 | 01106121 | $20.00 |
| PIC/AVR PROGRAMMING ADAPTOR BOARD | JUNE 2012 | 24105121 | $30.00 |
| CRAZY CRICKET/FREAKY FROG | JUNE 2012 | 08109121 | $10.00 |
| CAPACITANCE DECADE BOX | JULY 2012 | 04106121 | $20.00 |
| CAPACITANCE DECADE BOX PANEL/LID | JULY 2012 | 04106122 | $20.00 |
| WIDEBAND OXYGEN CONTROLLER MK2 | JULY 2012 | 05106121 | $20.00 |
| WIDEBAND OXYGEN CONTROLLER MK2 DISPLAY BOARD | JULY 2012 | 05106122 | $10.00 |
| SOFT STARTER FOR POWER TOOLS | JULY 2012 | 10107121 | $10.00 |
| DRIVEWAY SENTRY MK2 | AUG 2012 | 03107121 | $20.00 |
| MAINS TIMER | AUG 2012 | 10108121 | $10.00 |
| CURRENT ADAPTOR FOR SCOPES AND DMMS | AUG 2012 | 04108121 | $20.00 |
| USB VIRTUAL INSTRUMENT INTERFACE | SEPT 2012 | 24109121 | $30.00 |
| USB VIRTUAL INSTRUMENT INT. FRONT PANEL | SEPT 2012 | 24109122 | $30.00 |
| BARKING DOG BLASTER | SEPT 2012 | 25108121 | $20.00 |
| COLOUR MAXIMITE | SEPT 2012 | 07109121 | $20.00 |
| SOUND EFFECTS GENERATOR | SEPT 2012 | 09109121 | $10.00 |
| NICK-OFF PROXIMITY ALARM | OCT 2012 | 03110121 | $5.00 |
| DCC REVERSE LOOP CONTROLLER | OCT 2012 | 09110121 | $10.00 |
| LED MUSICOLOUR | NOV 2012 | 16111121 | $25.00 |
| LED MUSICOLOUR Front & Rear Panels | NOV 2012 | 16111122 | $20 per set |
| CLASSIC-D CLASS D AMPLIFIER MODULE | NOV 2012 | 01108121 | $30.00 |
| CLASSIC-D 2 CHANNEL SPEAKER PROTECTOR | NOV 2012 | 01108122 | $10.00 |
| HIGH ENERGY ELECTRONIC IGNITION SYSTEM | DEC 2012 | 05110121 | $10.00 |
| USB POWER MONITOR | DEC 2012 | 04109121 | $10.00 |
| 1.5kW INDUCTION MOTOR SPEED CONTROLLER (NEW V2 PCB) | DEC 2012 | 10105122 | $35.00 |
| THE CHAMPION PREAMP and 7W AUDIO AMP (one PCB) | JAN 2013 | 01109121/2 | $10.00 |
| GARBAGE/RECYCLING BIN REMINDER | JAN 2013 | 19111121 | $10.00 |
| 2.5GHz DIGITAL FREQUENCY METER – MAIN BOARD | JAN 2013 | 04111121 | $35.00 |
| 2.5GHz DIGITAL FREQUENCY METER – DISPLAY BOARD | JAN 2013 | 04111122 | $15.00 |
| 2.5GHz DIGITAL FREQUENCY METER – FRONT PANEL | JAN 2013 | 04111123 | $45.00 |
| SEISMOGRAPH 3D | FEB 2013 | 01102131 | $20.00 |
| MOBILE PHONE RING EXTENDER | FEB 2013 | 12110121 | $10.00 |
| GPS 1PPS TIMEBASE | FEB 2013 | 04103131 | $10.00 |
| LED TORCH DRIVER | MAR 2013 | 16102131 | $5.00 |
| CLASSIC DAC MAIN PCB | APR 2013 | 01102131 | $40.00 |
| CLASSIC DAC FRONT & REAR PANEL PCBs | APR 2013 | 01102132/3 | $20.00 |
| GPS USB TIMEBASE | APR 2013 | 04104131 | $15.00 |
| LED LADYBIRD | APR 2013 | 08103131 | $5.00 |
| CLASSIC-D 12V to ±35V DC/DC CONVERTER | MAY 2013 | 11104131 | $15.00 |
| DO NOT DISTURB | MAY 2013 | 12104131 | $10.00 |
| LF/HF UP-CONVERTER | JUN 2013 | 07106131 | $10.00 |
| 10-CHANNEL REMOTE CONTROL RECEIVER | JUN 2013 | 15106131 | $15.00 |
| IR-TO-455MHZ UHF TRANSCEIVER | JUN 2013 | 15106132 | $7.50 |
| "LUMP IN COAX" PORTABLE MIXER | JUN 2013 | 01106131 | $15.00 |
| L'IL PULSER MKII TRAIN CONTROLLER | JULY 2013 | 09107131 | $15.00 |
| L'IL PULSER MKII FRONT & REAR PANELS | JULY 2013 | 09107132/3 | $20.00/set |
| REVISED 10 CHANNEL REMOTE CONTROL RECEIVER | JULY 2013 | 15106133 | $15.00 |
| INFRARED TO UHF CONVERTER | JULY 2013 | 15107131 | $5.00 |

| PRINTED CIRCUIT BOARD TO SUIT PROJECT: | PUBLISHED: | PCB CODE: | Price: |
|---|---|---|---|
| UHF-TO INFRARED CONVERTER | JULY 2013 | 15107132 | $10.00 |
| IPOD CHARGER | AUG 2013 | 14108131 | $5.00 |
| PC BIRDIES | AUG 2013 | 08104131 | $10.00 |
| RF DETECTOR PROBE FOR DMMs | AUG 2013 | 04107131 | $10.00 |
| BATTERY LIFESAVER | SEPT 2013 | 11108131 | $5.00 |
| SPEEDO CORRECTOR | SEPT 2013 | 05109131 | $10.00 |
| SIDRADIO (INTEGRATED SDR) Main PCB | OCT 2013 | 06109131 | $35.00 |
| SIDRADIO (INTEGRATED SDR) Front & Rear Panels | OCT 2013 | 06109132/3 | $25.00/pr |
| TINY TIM AMPLIFIER (same PCB as Headphone Amp [Sept'11]) | OCT 2013 | 01109111 | $20.00 |
| AUTO CAR HEADLIGHT CONTROLLER | OCT 2013 | 03111131 | $10.00 |
| GPS TRACKER | NOV 2013 | 05112131 | $15.00 |
| STEREO AUDIO DELAY/DSP | NOV 2013 | 01110131 | $15.00 |
| BELLBIRD | DEC 2013 | 08112131 | $10.00 |
| PORTABLE-D MAIN BOARDS | DEC 2013 | 01111131-3 | $35.00/set |
| (for CLASSIC-D Amp board and CLASSIC-D DC/DC Converter board refer above [Nov 2012/May 2013]) | | | |
| LED Party Strobe (also suits Hot Wire Cutter [Dec 2010]) | JAN 2014 | 16101141 | $7.50 |
| Bass Extender Mk2 | JAN 2014 | 01112131 | $15.00 |
| L'il Pulser Mk2 Revised | JAN 2014 | 09107134 | $15.00 |
| 10A 230VAC MOTOR SPEED CONTROLLER | FEB 2014 | 10102141 | $12.50 |
| NICAD/NIMH BURP CHARGER | MAR 2014 | 14103141 | $15.00 |
| RUBIDIUM FREQ. STANDARD BREAKOUT BOARD | APR 2014 | 04105141 | $10.00 |
| USB/RS232C ADAPTOR | APR 2014 | 07103141 | $5.00 |
| MAINS FAN SPEED CONTROLLER | MAY 2014 | 10104141 | $10.00 |
| RGB LED STRIP DRIVER | MAY 2014 | 16105141 | $10.00 |
| HYBRID BENCH SUPPLY | MAY 2014 | 18104141 | $20.00 |
| 2-WAY PASSIVE LOUDSPEAKER CROSSOVER | JUN 2014 | 01205141 | $20.00 |
| TOUCHSCREEN AUDIO RECORDER | JUL 2014 | 01105141 | $12.50 |
| THRESHOLD VOLTAGE SWITCH | JUL 2014 | 99106141 | $10.00 |
| MICROMITE ASCII VIDEO TERMINAL | JUL 2014 | 24107141 | $7.50 |
| FREQUENCY COUNTER ADD-ON | JUL 2014 | 04105141a/b | $15.00 |
| VALVE SOUND SIMULATOR PCB | AUG 2014 | 01106141 | $15.00 |
| VALVE SOUND SIMULATOR FRONT PANEL (BLUE) | AUG 2014 | 01106142 | $10.00 |
| TEMPMASTER MK3 | AUG 2014 | 21108141 | $15.00 |
| 44-PIN MICROMITE | AUG 2014 | 24108141 | $5.00 |
| OPTO-THEREMIN MAIN BOARD | SEP 2014 | 23108141 | $15.00 |
| OPTO-THEREMIN PROXIMITY SENSOR BOARD | SEP 2014 | 23108142 | $5.00 |
| ACTIVE DIFFERENTIAL PROBE BOARDS | SEP 2014 | 04107141/2 | $10/SET |
| MINI-D AMPLIFIER | SEP 2014 | 01110141 | $5.00 |
| COURTESY LIGHT DELAY | OCT 2014 | 05109141 | $7.50 |
| DIRECT INJECTION (D-I) BOX | OCT 2014 | 23109141 | $5.00 |
| DIGITAL EFFECTS UNIT | NOV 2014 | 01110131 | $15.00 |
| DUAL PHANTOM POWER SUPPLY | NOV 2014 | 18112141 | $10.00 |
| REMOTE MAINS TIMER | NOV 2014 | 19112141 | $10.00 |
| REMOTE MAINS TIMER PANEL/LID (BLUE) | NOV 2014 | 19112142 | $15.00 |
| ONE-CHIP AMPLIFIER | NOV 2014 | 01109141 | $5.00 |
| TDR DONGLE | DEC 2014 | 04112141 | $5.00 |
| MULTISPARK CDI FOR PERFORMANCE VEHICLES | DEC 2014 | 05112141 | $10.00 |
| CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD | DEC 2014 | 01111141 | $50.00 |
| CURRAWONG REMOTE CONTROL BOARD | DEC 2014 | 01111144 | $5.00 |
| CURRAWONG FRONT & REAR PANELS | DEC 2014 | 01111142/3 | $30/set |
| CURRAWONG CLEAR ACRYLIC COVER | JAN 2015 | | $25.00 |
| ISOLATED HIGH VOLTAGE PROBE | JAN 2015 | 04108141 | $10.00 |
| SPARK ENERGY METER MAIN BOARD | FEB/MAR 2015 | 05101151 | $10.00 |
| SPARK ENERGY ZENER BOARD | FEB/MAR 2015 | 05101152 | $10.00 |
| SPARK ENERGY METER CALIBRATOR BOARD | FEB/MAR 2015 | 05101153 | $5.00 |
| APPLIANCE INSULATION TESTER | APR 2015 | 04103151 | $10.00 |
| APPLIANCE INSULATION TESTER FRONT PANEL | APR 2015 | 04103152 | $10.00 |
| LOW-FREQUENCY DISTORTION ANALYSER | APR 2015 | 04104151 | $30.00 |
| APPLIANCE EARTH LEAKAGE TESTER PCBs (2) | MAY 2015 | 04203151/2 | $15.00 |
| APPLIANCE EARTH LEAKAGE TESTER LID/PANEL | MAY 2015 | 04203153 | $15.00 |
| BALANCED INPUT ATTENUATOR MAIN PCB | MAY 2015 | 04105151 | $15.00 |
| BALANCED INPUT ATTENUATOR FRONT & REAR PANELS | MAY 2015 | 04105152/3 | $20.00 |
| 4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR | MAY 2015 | 18105151 | $5.00 |
| SIGNAL INJECTOR & TRACER | JUNE 2015 | 04106151 | $7.50 |
| PASSIVE RF PROBE | JUNE 2015 | 04106152 | $2.50 |
| SIGNAL INJECTOR & TRACER SHIELD | JUNE 2015 | 04106153 | $5.00 |
| BAD VIBES INFRASOUND SNOOPER | JUNE 2015 | 04104151 | $5.00 |
| CHAMPION + PRE-CHAMPION | JUNE 2015 | 01109121/2 | $7.50 |
| DRIVEWAY MONITOR TRANSMITTER PCB | JULY 2015 | 15105151 | $10.00 |
| DRIVEWAY MONITOR RECEIVER PCB | JULY 2015 | 15105152 | $5.00 |
| MINI USB SWITCHMODE REGULATOR | JULY 2015 | 18107151 | $2.50 |
| VOLTAGE/RESISTANCE/CURRENT REFERENCE | AUG 2015 | 04108151 | $2.50 |
| LED PARTY STROBE MK2 | AUG 2015 | 16101141 | $7.50 |
| ULTRA-LD MK4 200W AMPLIFIER MODULE | SEP 2015 | 01107151 | $15.00 |
| 9-CHANNEL REMOTE CONTROL RECEIVER | SEP 2015 | 15108151 | $15.00 |
| MINI USB SWITCHMODE REGULATOR MK2 | SEP 2015 | 18107152 | $2.50 |
| 2-WAY PASSIVE LOUDSPEAKER CROSSOVER | OCT 2015 | 01205141 | $20.00 |
| ULTRA LD AMPLIFIER POWER SUPPLY | OCT 2015 | 01109111 | $15.00 |
| ARDUINO USB ELECTROCARDIOGRAPH | OCT 2015 | 07108151 | $7.50 |

## NEW THIS MONTH

| | | | |
|---|---|---|---|
| FINGERPRINT SCANNER – SET OF TWO PCBS | NOV 2015 | 03109151/2 | $15.00 |
| LOUDSPEAKER PROTECTOR | NOV 2015 | 01110151 | $10.00 |

# OOPS!
# Did You Miss a BIRTHDAY? Or FATHER'S DAY?
# Hey, it's only 7 weeks 'til CHRISTMAS!

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**Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au**

## Tela Verta radio for sale

I have a Tela Verta 1948 Mantel Radio which I want to sell. It is the same one as featured in your March 2015 issue and it is in working order. It was my grandfather's and I'm not sure where I should list it for sale and how much it is worth. Hoping you can help with some information. (S. S., via email).

● We suggest contacting the Historical Radio Society of Australia. Their phone number is (03) 9539 1117 and their website is at www.hrsa.asn.au

They have auctions and we believe they also have a forum on their website for selling vintage radios. Membership of the association is $35. If your radio is in good condition, considering the age and the fact that it's operational, it should be well worth the effort to sell it to a collector.

## Problems with Barking Dog Blaster

I have built three Barking Dog Blasters (SILICON CHIP, September 2012), all from kits purchased from Altronics, and I have a couple of problems. The instructions refer to a testing tone which is achieved by holding the Start button down while applying power. I don't know why but none of the three units I have built will give this test tone. The LED behaves as described. Using an oscilloscope I have verified the presence of the ultrasonic wave on all the units.

The other issue is that there seems to be a large signal loss between the unit and the speaker box when measured with the oscilloscope. The unit I am currently working on uses 15 metres of figure-8 twin flex for this connection, which I would not have expected to give this sort of loss. I am uncertain whether the amount of signal at the speaker is adequate to provide the desired result. (B. D., via email).

● Changing to an audible testing tone should be done after you are sure the 5V supply has dropped to almost 0V. Then make sure the start switch is held down and reapply power. If that still does not work, it may be a programming fault with IC1. If the ultrasonic output appears correct, you probably do not need to be concerned since you can check that the output is there with the oscilloscope rather than using the audible setting.

As far as signal loss is concerned over a 15m figure-8 cable, make sure the oscilloscope measurement is compared between the output terminals on the barking Dog Blaster at CON3 and at the other end of the wires before the filter comprising the 47Ω resistor and inductor L1. There is significant difference in the signal when measured across the tweeters.

If there is loss along the 15m wiring, make sure that the wire length does not contribute significant resistance. Using heavier duty wire and separating the figure-8 cable's wires may reduce losses.

## How to build a motorised barrow

I am interested in building a motorised trolley for the garden, something like a self-propelled wheel-barrow, able to carry firewood logs or gravel up hills etc. Now the electronic side of me says use an electric motor but how to choose a powerful load-bearing unit? How do I compare the available motors for torque, wattage etc in such an application? Permanent magnet motors rated at around 300-600W are big, heavy and expensive. Brushless 1-2kW electric motors, even with controllers, are similar in price to the permanent magnet 500W motors.

Could a starter motor from a car be used and controlled or should I make an in-wheel F&P washing machine motor? But then I would have no abil-

## Loudspeaker Foam Surrounds Are Liable To Perish

I'm thinking of building the Majestic Loudspeaker but I have some questions. Why is the woofer cut-off point at 1.6kHz? On DIY speaker sites, they say 2-way systems are not good enough to split the audio spectrum properly. They say that because human ears are more sensitive to midrange sounds rather than lows and highs, a 3-way system is better.

The Etone factory said they can make the Etone 15-inch woofer with a foam surround. I would prefer this one. Could it push the lows further down? Or would it be too low and only reproduce rumble and would the cone destroy itself?

What would happen with the sound if I use solid timber instead of plywood? Would the bass be more solid? And does SILICON CHIP plan to make a big 3-way system in the future? (J. S., via email).

● The crossover frequency has been selected for the smoothest overall frequency response. While there are excellent 3-way systems, the design of a 3-way crossover is much more critical and there are a lot more phase changes across the spectrum. Also, most midrange drivers do not perform as well as the best tweeters and having the tweeter cover more of the midrange gives better location of musical instruments in the stereo "stage".

We would not choose a foam surround; they are more liable to perish, especially if you live in a humid climate. Plywood is actually stronger and more rigid than timber of the same thickness, so it should give a more rigid and non-resonant cabinet.

We have no immediate plans to do a 3-way system.

## Ignition System For Prototype Aircraft Engine

Greetings from across the ditch. You produce a great magazine, with a bit of stuff for everyone. I have fiddled with radio and things electronic since XFG1s were about and transistors were just starting to become commercial.

I have developed an interest in the intervening period of time with new technologies of all types and especially thermodynamics, catalytic reactions, and the intermarriage of internal combustion engines and electrical hybrid power units. I have a number of patents in this and other areas and would suggest that this subject may be of interest to your readers.

Presently, I am prototyping an unusual variable torque stratified-charge engine aimed at the large drone, helicopter and light aircraft segment. Among other design aspects, this has inductively transparent bores with generation coils inside the water jacket, the whole thing being intended to be commutated, rectified and stored to be reused in a similar manner to an out-runner DC motor.

The other aspect is that the unit is designed to run six pistons in common bores as opposed pairs. The stroke is exceptionally short at 50mm so that the piston speed is quite low in relation to the maximum attainable revs (23,100 RPM) which brings me to my reason for contacting you. The ignition system requires six simultaneous sparks of long duration to ignite the small volume pre-chambers which are fuelled under high-pressure air and conventional petrol to form a normal 12-14:1 mixture.

The pre-chambers are about 3% of the main combustion chambers volume which is fuelled with a mixture strength approaching 50:1, the idea being that the enlarged flame front from the pre-chambers (two such chambers per cylinder) will ignite and combust the 50:1 fuel mixture under a non-knock-related process (any hydrocarbon, no octane requirement, multi fuel).

I have built a number of inductive, transistor, SCR, IGBT and Mosfet ignition systems with various trigger types, none of which I believe are optimum to achieve the ignition for this prototype. I do not wish to utilise a programmable design as the motor data will be required to be read with fixed degree increments to map the Bsfc torque etc. My overview would be to utilise a 12-350-400V inverter and charge six separate capacitors to light up the charge. I have been away from hands-on electronics for the last few years and there are probably ICs which have been designed for an entirely different purpose which might fit this bill.

Any and all suggestions appreciated. I look forward to your comments with interest. (K. S., via email).

● We published a Multi-Spark Capacitor Discharge Ignition in December 2014 and January 2015 that should be suitable, stepping up from 12V to high voltage and charging one or two capacitors. The multi-sparking extends the firing period. You will probably need more than one of these CDI units to charge six capacitors although if you are using a distributor that would not be necessary.

ity to gear it. Could you do an article comparing motor options for different applications? It would be good if you could include how to add gearing – chain and sprocket, vs battery drill type planetary, vs metal gears from an angle grinder (eBay replacement gear sets for under $10). (L. C., via email).

● We don't really have the expertise to produce a detailed article on this topic. Practically speaking though, a geared starter motor, as used on most Japanese cars, would seem to be the best bet: compact and reasonably light, with high torque and a relatively simple control circuit, although it would need to handle peak currents in the hundreds of amps.

## FM transmissions are cross-polarised

Can you please confirm the orientation of the 5-element Yagi antenna in the October 2015 issue? I had always thought that FM and DAB+ signals where vertically polarised but the article shows the antenna mounted horizontally. What would be the correct way to mount the antenna? (J. O., via email).

● All DAB+ transmissions are vertically polarised while FM transmissions are cross-polarised (ie, vertical & horizontal). This means that FM broadcasts can be picked up by car radios which have (vertical) whip antennas and also by TV antennas, most of which are mounted horizontally.

The 5-element FM Yagi is intended to be mounted horizontally. It cannot normally be mounted vertically (ie, with all elements in the vertical plane) as the metal mast would interfere with the resonant operation of the dipole and other elements.

Of course, if you had a non-metallic mast such as fibreglass or timber, then the antenna could be mounted with the elements in the vertical plane. This would have an advantage in that the elements would be unlikely to be bent because of birds perching on them but it would also mean that the antenna might have more windage.

With the DAB+ antenna featured in this month's issue, the boom must be clamped to the mast at a point behind the reflector element, so that it (ie, the mast) does not interfere with the resonant behaviour of the antenna's elements.

## Why build the 5-element FM antenna?

The article in the October 2015 issue is introduced with "Can't buy an FM Antenna? Build your own: it's easy!" The reason you can't buy specialised FM band antennas is that they are rarely needed. Even in a very difficult situation, a folded dipole with a Jaycar LT-3028 transformer and coax lead-in will do the job.

I am at Badgerys Creek, a considerable distance from the nearest FM transmitters in Sydney. From inside my living room I can demonstrate cheap battery-powered FM radios with telescopic antennas giving noise-free reception, not to mention two FM car radios, one in a car and one on my workbench.

Most FM listeners are in a similar situation. What would be the point in installing a 5-element beam? Also, the

## 12AX7 Valve Preamplifier

I would like to make the 12AX7 valve preamplifier and I want to purchase the PCB from your website. Do I need to buy two PCBs for my stereo preamplifier or will one PCB suffice? Also, can I buy quality parts from your site for this project? (S. S., via email).

- The valve amplifier has a single channel so you will need two boards for a stereo preamplifier. The accompanying high-voltage power supply board will drive the two preamp boards. We don't sell any of the other parts (except for RCA sockets, see below) but they are common types, available from just about any retailer.

The resistors are all standard 0.25W 1% or 1W 5% through-hole types. The capacitors are standard radial electrolytic or high-voltage polyester through-hole types. 12AX7 valves are available from websites like eBay and Ali Express.

You will need to use a little care in selecting the valve sockets to make sure they will fit the PCB. They look like this: http://www.aliexpress.com/item/KL-2014-new-10pcs-lot-GZC9-C-1-Small-9-pin-scaffolding-tube-socket-tube-sockets/32365919714.html?spm=2114.031010208.3.66.Nk5Fsi&ws_ab_test=201407_1,201444_6,201409_1

Assuming that photo is accurate, those sockets should be OK. The PCB is designed for 3-pin switched RCA sockets. We can supply these from: www.siliconchip.com.au/Shop/7/2615

They aren't a perfect fit but the pins can be bent to fit the PCB and they will do the job. These are the ones the PCB is designed for but you may have trouble getting them outside Australia: www.jaycar.com.au/Interconnect/Plugs%2C-Sockets-%26-Adaptors/RCA/PC-MOUNT-RCA-Socket/p/PS0279

We plan to produce an updated stereo version of the 12AX7 valve preamplifier within the next couple of months.


## MISS THIS ONE?

Published in Dec 2012

## 2.5GHz 12-Digit Frequency Counter

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introduction on page 72, says, "you'll be amazed at how good those stations can sound when they have a strong signal." This statement shows a complete lack of knowledge of the nature of FM receivers. Provided the limiters are fully saturated, increasing the incoming signal by 1000 times makes no difference to the sound quality.

On page 73 is an impressive drawing showing the mechanics of the antenna. It specifies 19mm square aluminium tubing. How many hardware stores would stock this? In my career, I have designed, manufactured and tested many Yagi-type antennas for frequencies between 15MHz and 170MHz. Most of these had to comply with a definite specification. In my ham radio days, I designed a beam for the 144MHz band using only wooden curtain rods and insulated copper wire. I didn't have the time to measure its characteristics but it worked well. Translated to the FM band, it would cost a fraction of your October 2015 design and be easier to make. (M. F., via email).

- You make a lot of points. First, it is true that you can get passable reception on a FM portable receiver or a car radio with just the whip antenna. However, you really cannot use those to make any qualitative judgement of sound quality. For a start, most portables will only be mono, with a tiny speaker and limited response, both in the bass and treble range. In fact, the term "passable" is probably way too complimentary. Did you test the "quieting characteristics" of these radios with an FM signal generator before you did those subjective reception tests?

Most car radios would be pushed to provide ultimate quieting of better than -50dB in mono mode and would be unlikely to be better in stereo. Battery-powered portables would be worse. As for low distortion, forget it. For really good stereo sound you need ultimate quieting of at least -65dB, to get low harmonic distortion and hiss-free reception on a wide-range sound system.

And it is true that provided an FM tuner has enough signal to saturate the limiter, further increases in signal will not improve the signal-to-noise ratio or the sound quality. However, EMI from various sources inside a typical


## MISS THIS ONE?

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Published in Feb 2013

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***PCBs, micro etc available from On-Line Shop***

## Questions On The Ultra-LD Mk.4 Amplifier Module

I have some questions regarding the 200W Ultra-LD Mk4 Amplifier module (SILICON CHIP, August - October 2015) but they also apply to the Mk3 version.

On the question of biasing, the collector of the Q5 is two $V_{BE}$ drops above the Speaker Out voltage and Q6's collector is two $V_{BE}$ below Speaker Out. The amplifier has a gain of unity at DC. The input, ie, the base of Q1a, is (roughly) tied to ground (via a 12kΩ resistor). The DC gain of unity will therefore put the Speaker Out voltage at about ground and therefore the base bias of ground for Q1b. This would also explain how the collectors of Q5 and Q6 are biased at about 65V, as shown. Is this correct?

I am not sure about diodes D1a/b. Presumably they are there to protect the 1000µF electrolytic capacitor from reverse voltages? Similarly, D3 & D4 are there to protect from improper connection. If so maybe moving the fuses to the right of the diodes may be better placement. Thanks for an interesting set of articles. (A. B., via email).

● You are basically correct but we would state the situation a little differently. A fixed amount of current flows from the positive supply through Q5, then DQ10/DQ11, then Q9, then DQ12/DQ13, then Q6 to the negative supply. Since Q5 holds the current at a fixed value, the voltage between the collectors of Q5 & Q6 is set by the bias network of DQ10/DQ11/Q9/DQ12/DQ13. This is arranged to give 2-2.2V across the bias network at all times.

Thus as Q6's collector voltage varies, Q5's collector voltage tracks it but ~2V higher. This voltage ensures that Q7-Q13 all have base current flow with the output sitting at 0V. This current comes from Q5 – part of it flows through the bias network and part through the output transistor base-emitter junctions.

The voltage at the collectors of Q5 & Q6 effectively tracks the output voltage and differs only by the base-emitter junctions in the output stage. With the output at 0V, due to the voltage across the bias network, Q5's collector is around 1V above ground and Q6's collector around 1V below it.

There is a small voltage across the 12kΩ resistor at the input (~10mV) due to Q1a's base current. The feedback system maintains Q1b's base voltage at a similar level. If the 1000µF 6.3V capacitor is shorted out, this would mean the DC voltage at the speaker output would be around 240mV (due to the action of the feedback divider) which is too high. Reducing the DC gain to one reduces this to the same 10mV figure which is acceptable (and which can be mostly trimmed out using VR2).

Yes, D1a/b protects the capacitor in case there is a DC fault at the output. If the output swings to -57V, the capacitor would be charged to -2.32V with a bias current of around 4mA. While it's unlikely that this would cause immediate damage, it could eventually remove its oxide layer. The diodes conduct first.

D3 & D4 are there to absorb any inductive spikes fed back into the speaker output from a line transformer or electrostatic speaker transformer. They would quickly burn out if the supply was reverse-connected. If they were connected behind the fuses, the fuses would blow in this case but the front end would still be exposed to the reverse voltage and damage would be inevitable.

Moving D3 & D4 to the other side of the fuses would only protect the output stage. You really just have to be careful not to get the supply polarity reversed.

modern home, such as an NBN modem, some DVD players, compact fluorescent lamps and LED down-lights with electronic ballasts etc, can easily block any FM reception if you are using a simple dipole antenna or worse, an extendable whip. A decent external roof-mounted antenna with a good quality coax cable is the only sure way to ensure clean, noise-free reception.

But the other reason to build a higher gain, more directional antenna like our 5-element design is to combat multi-path reception which can cause quite objectionable sound quality problems. Your location is on the flat with no surrounding hills or tall buildings, so you would probably not experience multi-path reception. Possibly you don't have problems with EMI in your home, as well. If so, you are fortunate.

Finally, the 19mm square tube is available from any Bunnings store (Australia wide), a fact that should have been mentioned in the article. The cost is not high. How long would you expect a wooden antenna with insulated copper wire to last in Sydney, with flocks of cockatoos on the rampage? In many locations it would not last a week.

## Theremin won't adjust the volume

I purchased two Theremin kits from Jaycar (SILICON CHIP, March 2009) and I experienced a few issues. Once I completed them I applied power. Then I tested TP1 & TPG and the voltage was 9V. Then I adjusted coil T2. My problem is that whenever I tried to adjust the volume disc it didn't adjust the gain. I connected my multimeter between TPGND & TP2 and the reading was only 0.17V.

Also the volume control pot VR1 does nothing and the overall gain is very low. I had the same results for both units. Do you have any advice on what to do? (E. G., via email).

● Make sure that diode D3 is installed with the correct orientation and that Q4 is a BC548 and that Q1-Q3 are 2N5484s. Check the resistor values, especially those around IC2a and Q4.

The volume alignment must be adjusted exactly as described under the Volume Adjustment section of the article (page 40, March 2009). A reading of 0.17V at TP2 suggests the adjustment with T3, T4 and VR3 is not correct. It will not be possible to adjust T4's slug correctly if T3 is not correctly adjusted first.

## CDI for an old 2-cylinder engine

Is there any technical information available about the Capacitor Discharge Ignition Kit for Motor Bikes (Jaycar Cat. KC5466)? I am wondering if I can use this to retrofit an Onan

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## Ask SILICON CHIP

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2-cylinder engine, circa 1940. (J. S., via email).

● The article is available at **www.siliconchip.com.au/Issue/2008/May/Replacement+CDI+Module+For+Small+Petrol+Motors**

The CDI should work with most small engines that include a high-voltage generator coil in the flywheel. Depending on the arrangement, you may require two CDI units for your 2-cylinder engine. With some engines, there is ignition firing on both cylinders at the same time (called a wasted spark) where the plug fires near bottom dead centre of the piston for a 2-stroke or during the exhaust stroke for a 4-stroke, thus having no effect.

## Headphone switch box

I have always admired your magazine, specifically for the audio projects. I have a high-quality headphone amplifier with a single ¼-inch (6.35/6.5mm) phono socket. I would like to use that single outlet for switching between two pairs of headphones for comparison reasons. I thought I could just buy a switch-box suitable for that but I can't find one. I've checked hifi shops and asked Jaycar Electronics about building one etc.

What I would like is a high-quality headphone switch-box ideally configured with one stereo phone input and four stereo phone sockets, with only one of the four outlets active at any one time. I would like two of these

*. . . continued on page 96*

## Notes & Errata

**Appliance Earth Leakage Tester, May 2015:** the parts list includes one 100nF MKT capacitor but two are required.

**Ultra-LD Mk.4 Power Amplifier Module, July-September 2015:** the parts list on page 38 of the August 2015 issue gave an incorrect part number for the 4.7V zener diodes. It should be BZX84B4V7-7-FDICT-ND. The ferrite bead type isn't critical but we suggest Digi-Key 240-2548-1-ND.

**9-Channel IR Remote Control Receiver (September 2015):** a bug in the receiver code could cause the last used function to be repeated in the presence of interference. The revised code 1510815B.hex fixes this.

## Ask SILICON CHIP

*. . . continued from page 95*

switch-boxes, built with the best quality audio quality components. Do you know where a switch-box anything like this is available? Alternatively, where I can get suitable parts to build one (I haven't been able to find a good 4-way switches, for phono use in particular)?

Ideally I'd like a 4-outlet switch-box but anything with at least two outlets would be acceptable. The only option I've been able to find so far is to use a different headphone amplifier (made by Musical Fidelity) which has dual phono outlets (non-switchable) but could do the job if I'm willing to spend some money (either $350 or $900) to downgrade the quality of my headphone amplification by using it.

If I can't buy something like this or get it built anywhere, where is an electronics shop that could custom design and build it for me? Could consider having 10-100 of them made and reselling them though headphone shops if need be, if I can't get just two. I hope you can point me in a good direction. (G. C., via email).

● We published a Two-Way Stereo Headphone Adaptor in the April 2008 issue which can switch between two sets of headphones. However, the fact that there are resistors and pots in the signal path, with no buffering, means that it would not meet the high standards for distortion set by the Studio Series Headphone Amplifier (SILICON CHIP, November 2005) and more particularly, by the much higher performance headphone amplifier described in the September & October 2011 issues.

With your existing set-up, all you really need are three 12V DPDT relays wired up to a rotary switch (or similar) such that the coils are energised to connect the input socket to one of the four output sockets. It can be totally passive and as long as the wiring is kept short and the whole thing is housed in an earthed metal case, it will have negligible effect on sound quality. After all, we pass hundreds of watts from a power amplifier through a 10A DPDT relay in our speaker protector module with virtually no measurable effect on sound quality.

At the much lower voltage/current/power levels for driving headphones, and given the higher load impedances, as long as good quality relays are used it should be fine. SC

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## Next Issue

**The December 2015** issue of SILICON CHIP is due on sale in newsagents by Thursday 26th November. Expect postal delivery of subscription copies in Australia between November 25th and December 7th.


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SILICON CHIP magazine regularly describes projects which employ a mains power supply or produce high voltage. All such projects should be considered dangerous or even lethal if not used safely.

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# Drypower

## Rechargeable Lithium LiFePO4

The **Drypower Rechargeable Lithium** - lithium iron phosphate (LiFePO4) - battery features the latest in portable power technology as a result of years of extensive research. Drypower Rechargeable Lithium gives you batteries with superior performance in industrial or high drain applications featuring high energy output, deep cycle power, rechargeability with long service life, and portability. Standard (E2) and Smart (E3) battery types available.

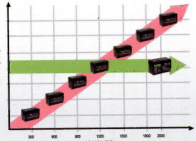
Switching to rechargeable lithium battery technology where traditional Sealed Lead Acid (SLA) batteries are currently used eliminates the issues usually experienced with SLA batteries:- bulky, heavy and costly to maintain.

### HIGH PERFORMANCE BATTERIES

The benefits of implementing Drypower LiFePO4 high performance batteries over SLA batteries include:

- **LONGER SHELF LIFE**
  Up to 3X longer than SLA.
- **HIGH TEMPERATURE TOLERANCE**
  Up to +60°C discharge. SLA rated @24°C.
- **SUPERIOR CYCLE LIFE**
  Up to 2000 discharge cycles.
- **LONGER SERVICE INTERVALS**
  Once every 7-8 years.

### LOWER TOTAL COST of OWNERSHIP vs SLA




### BUILT IN SAFETY (PCM)

Electrical protection for safety.

### SUPERIOR EFFICIENCY

Faster charging & discharging.

### PORTABILITY

1/3 weight of SLA equivalent.

### WIDE RANGE

6V and 12V models with various capacities & terminations.

**GOT A REQUEST?**
If you've been looking for a high power solution for your application and are interested in what Drypower Rechargeable Lithium could do for you, contact the specialist team at Master Instruments.

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